SPACEPOWER FOR AUSTRALIA'S SECURITY—
GRAND STRATEGY OR STRATEGY OF GRANDEUR?

BY

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A THESIS PRESENTED TO THE FACULTY OF

THE SCHOOL OF ADVANCED AIR AND SPACE STUDIES

FOR COMPLETION OF GRADUATION REQUIREMENTS

SCHOOL OF ADVANCED AIR AND SPACE STUDIES

AIR UNIVERSITY

MAXWELL AIR FORCE BASE, ALABAMA

JUNE 2012

APPROVAL

The undersigned certify that this thesis meets master's-level standards of research, argumentation, and expression.

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ACKNOWLEDGMENTS

I am extremely fortunate to have been invited to study strategy for a year at the School of Advanced Air and Space Studies. The faculty has unfailingly inspired me through their expertise and passion in what has been an outstanding course. In particular, I thank Dr. Everett Dolman for the always-stimulating discussions on spacepower and strategy, and guidance as my advisor for this thesis. I also thank Dr. John Sheldon who helped shape the thesis at inception, and provided invaluable advice and editing to assist in its completion.

To my SAASS XXI classmates, thank you for welcoming an Aussie into the mix, and your insight into the inner workings of a military superpower.

Most importantly, I would like to thank my wife for her unstinting support and understanding throughout the year. I know that deep down, perhaps very deep, she thoroughly enjoyed the discussions we had on strategy, military history, and systems theory.

ABSTRACT

Spacepower For Australia's Security—Grand Strategy Or Strategy Of Grandeur? contends that Australia needs to incorporate spacepower as an element of its grand strategy. An analysis of the meaning of strategy and grand strategy in the modern context of twenty first century power leads to a proposition that a more complex world requires a different view of strategy, one viewed through a systems lens. The effectiveness of risk analysis to strengthen national security is evaluated and shown to be deficient for complex systems with highly improbable but highly consequential events. An alternative view for developing strategy for complex systems is proposed that contributes the concept of system resilience. A theory of spacepower is developed following a comparison between the land, air, sea and cyber domains. Spacepower emerges as a unique element of national power, and an essential element of grand strategy for the twenty first century. An understanding of the unique territory of space, the dimensions of strategy relevant to spacepower and Australian national security, and outputs from the space system supports the thesis that *space systems* underpin modern society to such an extent they form an important, yet presently overlooked element of grand strategy.

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INTRODUCTION

Sputnik's blazing launch into orbit heralded the dawn of a new space age. This unassuming, round, basketball sized transmitter captured the attention of a world as its path brought it overhead the world's capital cities, day after day for three weeks.[1] From a perspective of state survival and political prestige, the specter of Sputnik in orbit, overflying the boundaries of national territory intensified divisions between nation-states as they sought to dominate the emergent technology to bolster their own power. Economically, it resulted in an explosion of space related expenditure for many nations, pushing them closer, or deeper, into technocracy.[2]

The magnitude of shock produced is worth reflecting on, for the technologies that are required to launch a satellite into space were being steadily developed by other countries such as the US well before the debut of *Sputnik*. Technologies needed for space flight, such as propulsion, guidance, communications, material structures, and a myriad of other elements—all were within the technological capability of the US. *Sputnik* in orbit, many argued, proved the US was behind in a great race. However, this gives too much credence to the most visible element of the system—an orbiting metal sphere (albeit a technological marvel at the time) orbiting the Earth—and diminishes the importance of the complex underlying system needed to get it there. Transposed to the present, and the perception is still the same; many see spacepower only in terms of orbiting satellites, as versions of *Sputnik* in different form.

When Wilbur and Orville Wright first left the clutches of the earth on December 17, 1903, in a heavier-than-air machine, it too heralded the

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[1] Steven James Lambakis, *On the Edge of Earth : the Future of American Space Power* (Lexington, Ky.: University Press of Kentucky, 2001), 13.
[2] Walter A McDougall, *The Heavens and the Earth : a Political History of the Space Age* (Baltimore, Md.: Johns Hopkins University Press, 1997), 157.

birth of a new age, that of the airplane. To the public and layman alike, the most obvious and visible aspect of these new wonders was the technological platform itself. Whether it was a wood and wire flying structure or an Earth orbiting sphere, few understood how the platform worked, and fewer still understood what it took to get there.

The success of the Wright brothers had less to do with developing the technology to get a machine into the air, and much more to do with their approach to developing an understanding of a system. A crucial understanding of flight control preceded their actual design, and experiments to develop lift theory were subsequently translated into wing and propeller design.[3] This differentiated them from other inventors who tried to copy the forms of flight, such as that of birds, without understanding why. These and other seemingly unrelated developments were tied into a holistic whole, so they saw what others had not—the need to warp a wing for flight control influenced the structure, structure affected weight, which dictated propulsion, which influenced structure, and so on in a system of feedbacks and interrelatedness.

Few today fully understand the *systems* supporting modern flight. The flying platform in and of itself is a complex structure with thousands of interconnected systems, and underpinning these are a myriad of other systems: air traffic control, aerodromes, design standards and legislation, inspection regimes, maintenance schedules, training and education, and tens of thousands of complex supply chains. All are relatively invisible to the lay observer, or consumer of flight.

In a similar way for space, *Sputnik* was enabled through the developments of scientists and engineers in the years preceding the launch. Johannes Kepler and Tycho Brahe developed kinematics of motion in the early seventeenth century, which underpinned Isaac

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[3] *Encyclopedia of Creativity 2, I - Z, Indexes.* (San Diego, Calif.: Academic Press, 1999), 724.

Newton's development of the mathematics describing the dynamics of motion that formed the basis for so much of our understanding motion in space.[4] Then, Tsiolovsky, Oberth, Goddard, and others solved incomplete parts of the puzzle.[5] Overall, this indicates a timeframe measured in centuries, and demonstrates the critical nature of the science needed just to theorize what might be possible, let alone the breakthroughs in metallurgy, rocketry, computing, and guidance that were required for the next, but not final, step.

The space system of today fundamentally supports a vast network of arterial systems that feed and support modern society. They are also the *essential* constituents necessary for a modern, Western style of warfare that is hostage to the use of precision weapons, a need for intelligence to mitigate risk, and global communications reach. An adage familiar to the strategist is that the more important a capability becomes as a source of strength, the more likely it is to be targeted by those wishing to gain advantage from its loss. This is a view that does not recognize the potential complexity of the situation; it simply ascribes importance to effect, and charges that those seeking to force an advantage over an opponent target the *object* of importance. A more accurate statement that recognizes a *total system* capability is—the more vital a capability becomes as a source of strength, the greater the *consequence* if it is disrupted, and hence the greater is its risk to the *system* to which it belongs. The object of importance, often targeted in the form of a particular aircraft, ship, or satellite, does not, nonetheless, constitute the system.

Given this interpretation, an assessment of Australia's reliance on the space *system* should lead to recommendations to enhance its

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[4] David A Vallado and Wayne D McClain, *Fundamentals of Astrodynamics and Applications* (New York: Springer, 2007), 9.
[5] Roger R Bate, Donald D Mueller, and Jerry E White, *Fundamentals of Astrodynamics* (New York: Dover Publications, 1971), 151.

national security in a spacepower context. However, the difficulty lies in understanding reliance for a system that is complex, interdependent, built of many disparate elements, and is now optimized to rely on the space system in ways that are undergoing continuous and rapid evolution. Through a systems lens, it is clear that the space system is of fundamental importance to Australian society and national security.

It arguably follows that to mitigate risk and improve resilience Australia should invest extensively to become a spacefaring nation by producing, launching and managing spacecraft systems—a conventional response to such a claim, and one representing a *strategy of grandeur*. However, no such claim is made here. Spacepower is fundamental to Australia's security and must intertwine with grand strategy, but this need not be a strategy of unrealistic grandeur.

Overview

Chapter 1, *Simply Strategy* assesses the meaning of strategy and grand strategy in the modern context of twenty first century power. Grand strategy, and its relationship with military power, is assessed from a theoretical perspective, followed by a proposition that a more complex world requires a different view of strategy—one viewed through a systems lens.

Chapter 2, *Strategy for Complex Systems* makes the case that the modern world is characterized by complexity, non-linearity, and exponential growth. Therefore, modern strategy is difficult, and should be considered under the broader view of grand strategy. The effectiveness of risk analysis to strengthen national security is evaluated and shown to be deficient for complex systems with highly improbable but highly consequential events. An alternative view for developing strategy for complex systems is proposed that contributes the concept of system resilience.

Chapter 3, *Spacepower Theory* begins with an examination of extant spacepower definitions and their development, concluding that the theory has been confusing. A theory of spacepower is developed following a comparison between the land, air, sea and cyber domains. Spacepower emerges as a unique element of national power, and thus must be viewed as an essential element of grand strategy for the twenty first century.

Chapter 4, *Framing Spacepower* argues that the space system is often simplistically seen as a constellation of individual elements, a view detrimental to grand strategy. These elements need to be considered as a holistic system, and that this system is complex changes the way spacepower is viewed as an element of national power. As a largely un-modeled complex system, it is difficult to establish with any degree of scientific rigor that space systems are critical to Australia's economic, cultural, and security well-being. Consequently, a systems analysis and framing of relevant elements of the space system is presented and discussed to cater for system complexity. The discussion produces an outcome from each assessment to produce strategic theory, whose central purpose is to connect disparate activities; in this case, to demonstrate the link between Australian national security and spacepower.[6] An understanding of the unique territory of space, the dimensions of strategy relevant to space and Australia, and outputs from the space system supports the thesis that *space systems* underpin modern society to such an extent they form an important, yet presently overlooked element of grand strategy. Finally, a spacepower sensitive interpretation of Australia's strategic position is offered, in tune with Australia's status as a middle power situated in a dynamic region of growing powers.

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[6] Colin S Gray, *Explorations in Strategy* (Westport, Conn.; London: Praeger, 1998), 4; See also Everett C Dolman, *Pure Strategy: Power and Principle in the Space and Information Age* (London; New York: Frank Cass, 2005), 6.

Chapter 1

Simply Strategy

Carl Von Clausewitz wrote, "Everything in strategy is very simple, but that does not mean that everything is very easy."[1] His subsequent clarifying sentence in *On War* explained that "simple" refers to the end state, not strategy *per se*. Perhaps for Clausewitz, it was simple. The end state was derived from political aims, and these were clear and well understood.[2] The element of implied difficulty, the reference to strategy not being easy is the *execution* of strategy—making the deliberate choices on the *means* to achieve the *ends*.[3] To be fair, Clausewitz was using a narrow definition of strategy, where engagements are for the purpose of war, and war results from an ultimate political aim.[4] Nonetheless, Clausewitz's era was markedly different to today, and the divination of political aims was simpler in the nineteenth century. In this new century, clear political aims are the exception, not the norm.[5] Accordingly, we can now say that strategy, also, is complex.

Modern Strategy

Strategy has many meanings, some specific to a particular industry or profession, some broad.[6] In Clausewitz's definition, "Strategy is the use of the engagement for the purpose of the war."[7] In *Modern Strategy,* Colin Gray liberally re-interprets the term engagements as used

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[1] Carl von Clausewitz et al., *On War* (Princeton, N.J.: Princeton University Press, 1984), 178.
[2] Clausewitz et al., *On War*, 178.
[3] Clausewitz et al., *On War*, 178.
[4] Clausewitz et al., *On War*, 177.
[5] Colin S Gray, *Modern Strategy* (New York: Oxford University Press, 1999), 356. Extrapolating Gray's contention that modern strategy is becoming more complex.
[6] Frans P. B Osinga, *Science, Strategy and War the Strategic Theory of John Boyd* (London; New York: Routledge, 2007), 9.
[7] Clausewitz et al., *On War*, 177.

by Clausewitz, redefining strategy as "the use that is made of force and the threat of force for the ends of policy."[8] The wording is important—by discriminating the use *that is made* of force, Gray's modern definition properly embraces the notion of nation-state power, whereby force is more than kinetic applications in war. It embraces the *potential* of force through deterrence, coercion, and the threat of the use of force, and places military power within the ambit of something larger, as one component of power within a grand strategy.[9]

Gray's definition of strategy conveys a sense of finality, the threat or use of force for an end, and is indicative of the older worldview as seen by Clausewitz. A definition with a temporal view is needed, and one that places military force in a wider purview of all the instruments of power available to the state. Modern strategy need not start *de novo*. Twenty-three hundred years ago, Sun Tzu first put the physical clash in a broader perspective, understanding that national strategy differed from military strategy; and a singular focus on military strategy, as being somehow distinct from the nation that provides its strength and purpose in being, was fundamentally flawed.[10] Everett Dolman renews the holistic view of power espoused by Sun Tzu. In *Pure Strategy,* he suggests that the military strategist must first discard the notion of victory and winning as tactical thinking—the pure strategist recognizes that war is just one element in an enduring competition.[11]

The integrated view of grand strategy has other historical origins: Thucydides described how Pericles enacted grand strategy by adopting a defensive approach to the direct offense of the Spartans, avoiding battle

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[8] Gray, *Modern Strategy*, 17.
[9] Dolman, *Pure Strategy*, 21.
[10] Sunzi and Samuel B Griffith, *The Illustrated Art of War* (New York: Oxford University Press, 2005), 62–63.
[11] Dolman, *Pure Strategy*, 5.

and husbanding their finances to deplete the overextended Spartans.[12] Liddell Hart placed grand strategy on a higher plane above 'mere' strategy; and John Slessor spoke of the need to account for moral, political, social and economic factors in addition to military.[13] A holistic, or integrated view of all the elements of power, not purely military power, constitutes the many dimensions of strategy—and failure to engage any one dimension invites failure of the whole.[14]

The foundation of practical strategy stems from two subordinate activities: first, an ability to define ends; and secondly, recognition of the many means available to achieve those ends—all in a coordinated whole which delivers ongoing advantage to the state.[15] This integrated view of how to best employ national power comes under the rubric of *grand strategy*, and is the process of weaving all the elements of national power together towards a political end-state.

Grand Strategy

Clausewitz warned, "There can be no question of a *purely* military evaluation of a great strategic issue, nor of a purely military scheme to solve it."[16] His collective thought in this vein has often been overshadowed by his (apparently) contradictory comments on the importance of decisive battle, as being somehow separate from the political aims—an end unto itself. Grand strategy discounts a purely military view, and rather focuses on a process of weaving in all the

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[12] Thucydides et al., *The Landmark Thucydides: a Comprehensive Guide to the Peloponnesian War; with Maps, Annotations, Appendices, and Encyclopedic Index* (New York: Simon & Schuster, 1998), 98.
[13] Basil Henry Liddell Hart, *Strategy* (New York, N.Y., U.S.A.: Meridian, 1991), 321–322; John Cotesworth Slessor, *Air Power and Armies* (Tuscaloosa: University of Alabama Press, 2009), 17.
[14] Gray, *Modern Strategy*, 25.
[15] *Pure Strategy*, 6.
[16] Citing Paret and Moran in; Peter Paret, Gordon Alexander Craig, and Felix Gilbert, *Makers of Modern Strategy: From Machiavelli to the Nuclear Age* (Princeton, N.J.: Princeton University Press, 1986), 200; Clausewitz et al., *On War*, 607.

elements of national power towards a political end state, where the political end state under consideration is national security.[17]

National security is the *primary* responsibility of the state, ensuring the state's survival and maintaining the governing political order.[18] At the state's behest, and for the grand strategist's consideration, are many types of power, the utility of which are a function of their applicable context. Two popular models demonstrating the many different forms of power for consideration include: DIME; diplomatic, information, military and economic; and also, PMESII; political, military, economic, social, infrastructure, and information systems.[19] National power is not just force, but force has its place.

For Clausewitz, the threat or use of force is what defined war and wartime, and intuitively war is the domain for strategy. However, strategy must properly be considered in both peacetime *and* in war. Therefore, it is essential to discriminate between the types of power used in peace and in war—as their utility will differ.[20] As Clausewitz avers, the first, the supreme, of all strategic questions, is to decide the type or kind of war upon which one is embarking.[21] Historically, the answer to this question has determined the dominant force used.

Airpower enabled coalition success in the opening stages of the first Gulf War, which paved the way for land power.[22] Maritime power dominated in the Pacific during WWII, though often as an expression of airpower launched from the sea. Landpower dominated in many other scenarios, but in the post conflict "peace", the same form of power often

[17] Dolman, *Pure Strategy*, 26.
[18] Gray, *Modern Strategy*, 46.
[19] Harry Richard Yarger, *Strategy and the National Security Professional Strategic Thinking and Strategy Formulation in the 21st Century* (Westport (Conn.); London: Praeger Security International, 2008), 71.
[20] Gray, *Modern Strategy*, 162.
[21] Clausewitz et al., *On War*, 88.
[22] John Andreas Olsen, *A History of Air Warfare* (Washington, D.C.: Potomac Books, 2010), 177.

led to poor results. For counter insurgency, economic and political power is as important, if not more so, than military power.[23] As a rule, grand strategy uses the many forms of power available, both military and non-military, despite the predominant nature of the domain.

However, there are a variety of competing views about the role of spacepower and strategy.[24] John Klein in *Space Warfare: Strategy, Principles and Policy,* argues that most space strategies are flawed because they lack "concerns related to diplomacy and economics", in other words, they lack a grand strategic view.[25] Spacepower is often seen only in terms of its domain, which is a form of weak, or limited grand strategy. If we are to address Klein's concern, the question that must be answered is: How does spacepower contribute to Australia's national security, being cognizant that it constitutes just one element of grand strategy?

Military Power and Strategy

Power in an international context is the measure of a state's ability to influence other actors in support of its own interests.[26] Although some argue the utility of hard military power is diminishing, military force—and its components such as spacepower—remain crucial elements for the future.[27] It is the fundamental premise of this thesis that military power in the form of spacepower is now so enmeshed within society that its loss would not only constitute a military defeat, but a national catastrophe. For the US, as the world's preeminent spacepower, tactical

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[23] Eric Schmitt and Thom Shanker, *Counterstrike : the Untold Story of America's Secret Campaign Against Al Qaeda* (New York: Times Books, 2011), 32.
[24] John J Klein, *Space Warfare : Strategy, Principles and Policy.* (London: Routledge., 2006), 13.
[25] Klein, *Space Warfare*, 18.
[26] Yarger, *Strategy and the National Security Professional Strategic Thinking and Strategy Formulation in the 21st Century*, 68.
[27] Joseph S Nye Jr., *The Future of Power: Its Changing Nature and Use in the Twenty-First Century.* (Public Affairs, 2011), 29–30.

victory in maintaining an advantage in space should in no way be considered strategic. Such a belief obscures the notion that the ongoing (tactical) advantage might be under serious (strategic) threat.

The first, most important, maxim expressed by Sun Tzu in *The Art of War* asserts, “War is a matter of vital importance to the State; the province of life or death; the road to survival or ruin.”[28] Although some deride the classical tenets of Sun Tzu as epigrammatic, lacking an overarching framework in the way Western strategists such as Clausewitz do, this first maxim is profoundly important. Max Weber in *Politics as a Vocation* explicitly links the notion of state to the exercise of force, where a political association that monopolizes the legitimate use of physical force is the satisfying condition for statehood.[29] From Sun Tzu two and a half thousand years ago to contemporary theory, a common theme suggests the defining purpose of a nation is security; specifically security for the state, security enabled by force. In other words, security enabled ultimately via military power.[30] Military power as an adjunct to politics merely provides *one* (albeit an important one) option for decision makers to achieve political ends.[31] While other forms of power are available, it is noteworthy that the fundamental enabler of these is the capacity for military power to provide “measured violence” at the will of the state.[32]

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[28] Sunzi and Griffith, *The Illustrated Art of War*, 91.
[29] Max Weber and Talcott Parsons, *The Theory of Social and Economic Organization* (New York: Free Press, 1964), 154.
[30] J F C Fuller, *The Foundations of the Science of War* (London: Hutchinson & Co., 1926), 68.
[31] Dolman, *Pure Strategy*, 33; Samuel P Huntington, *The Soldier and the State; the Theory and Politics of Civil-Military relations.* (Cambridge: Belknap Press of Harvard University Press, 1957), viii, 1.
[32] Gray, *Modern Strategy*, 46; Dolman, *Pure Strategy*, 33.

E.H. Carr firmly connects power as a decisive factor in all politics, cautioning that any other view is utopian.[33] Notwithstanding Carr's realist outlook, is a utopian view a necessarily flawed one as a basis for grand strategy? After all, the state must fund and provide for the military as just one amongst many elements of its power.[34] Robert Gilpin in *War & Change in World Politics* argues that it is more complex than an either/or debate about the primary purpose of the state. On one side, realists argue that national security is the primary objective of the state, on the other side, a modern approach argues that domestic economic stability and the welfare of the population is primary.[35] Gilpin offers a holistic view, where "every action or decision involves a trade-off, and the effort to achieve one objective inevitably costs with respect to some other desired goal."[36] In other words, maximizing security comes at a cost to society, and maximizing societal goals diverts resources from security—and all this is significant in a world of constrained resources and limited growth. Overemphasizing security may also bankrupt the state, thus negating the very economy that enabled its military means. The either/or debate is thus overly simplistic.

Joseph Nye expresses Gilpin's argument in another way. If military power is the fundamental enabler of other forms of power, then Nye accounts for the various other forms using a notion of smart power; a combination of the hard power of coercion (force and money) and the soft power of persuasion and attraction (institutions, ideas, values, and

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[33] Edward Hallett Carr, *The Twenty Years' Crisis, 1919-1939 : an Introduction to the Study of International Relations* (Houndmills, Basingstoke, Hampshire; New York: Palgrave, 2001), 216.
[34] Nye Jr., *The Future of Power: Its Changing Nature and Use in the Twenty-First Century.*, 52.
[35] Robert Gilpin, *War & Change in World Politics* (New York: Cambridge University Press, 1981), 19.
[36] Gilpin, *War & Change in World Politics*, 19.

culture).[37] This notion of smart power as an instrument of strategy accords well with the holistic view expressed thus far, and introduces a new degree of complexity and balance in assessing where to expend finite national resources.

The characteristics that make a nation good at strategy are no different from those that define a good enterprise, or a good family. From an understanding that strategy is all about relating ends to means, the first and most important characteristic is an ability to define a vision, a political end-state that is achievable with designated means. The second characteristic is an understanding that the means, while malleable in form, all come from the combined national resources available, and that excess in one area deprives another. Both these characteristics are conceptual, not structural. The argument is that structure derived from a theoretical basis is necessary before the nation can become good at strategy—form follows function.

For the military professional and layman alike, the application of force at its ultimate extreme is hard power—coercion, violence, compellence, and ultimately, destruction.[38] This extreme form of overwhelming force and massed effect has dominated warfare since the time of Thucydides and Sun Tzu. Its adherents who attest that this is the essential constituent of war include Von Moltke, Hedley Bull, and Clausewitz, who would all agree that war at its heart is violence—state sanctioned violence perhaps, but violence nonetheless.[39] Is this not simply the view of a pessimist, a representation of the realist paradigm that declares the international system is fundamentally one of anarchy

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[37] Nye Jr., *The Future of Power: Its Changing Nature and Use in the Twenty-First Century.*, xiii, 234.
[38] Nye Jr., *The Future of Power: Its Changing Nature and Use in the Twenty-First Century.*, 52.
[39] Hedley Bull, *The Anarchical Society : a Study of Order in World Politics* (New York: Columbia University Press, 2002), 184; Helmuth Moltke and Daniel J Hughes, *Moltke on the Art of War : Selected Writings* (Novato, CA: Presidio Press, 1995), 35.

and self-service? Colin Gray, a self-declared realist would answer this question in the affirmative, that the realism of pessimism trumps the optimism of (laudable) idealism.[40] In a reflection of Gray's realist view, the core of Australian security strategy is the "defence of Australia against direct armed attack … irrespective of the perceived intentions of others."[41]

This realist logic though raises a practical question—to what extent should military power, or force, be resourced? Certainly not to the calamitous extent where victory is pyrrhic, but neither so anemic that security is entirely dependent upon the good will of others.[42] In acknowledgement, Australian defence strategy articulated in the 2009 Defence White Paper leans towards *self-reliance* to deter and defeat an armed attack, but also accepts that some things, in terms of independent capabilities, remain out of reach.[43] By specifically referring to "space-based assets", it suggests that the essential requirement to control the air and sea approaches to Australia requires anything other than spacepower. This warrants further investigation, to determine the significance of spacepower as an essential element of Australian grand strategy. Indeed, this should resolve the question whether spacepower for Australia is fundamental to grand strategy, or merely a strategy of grandeur.

Maintaining security via the threat or use of force demands a thriving economy to underpin it, else it becomes a strategy of grandeur.[44] Without balance, as Sun Tzu pointed out, the cost of protracted

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[40] Gray, *Modern Strategy*, 10–11, 358.
[41] Australia. Dept. of Defence., *Defending Australia in the Asia Pacific Century: Force 2030: Defence White Paper 2009* ([Canberra]: Dept. of Defence, 2009), 12.
[42] On King Pyrrhus' lament, see Richard Holmes, *The Oxford Companion to Military History* ([New York]: Oxford University Press, 2004), 747.
[43] Australia. Dept. of Defence., *Defending Australia in the Asia Pacific Century*, 48.
[44] Nye Jr., *The Future of Power: Its Changing Nature and Use in the Twenty-First Century.*, 52.

campaigns may ruin the state.[45] Liddell Hart was similarly scathing of military strategy that focuses on the ends to the exclusion of the means, arguing that the wise ruler adapts aims in response to the limitations of the latter.[46] But the issue raised for spacepower, and its interface to grand strategy, is far more complex than the question of—self owned, or borrowed—space assets would suggest. I submit that the Australian view of a holistic world of grand strategy is presently built on a paradigm that is unable to deal with the complexity of the emergent system it finds itself in. As demonstrated by Thomas Kuhn in his seminal discussion on *The Structure of Scientific Revolutions,* we are often misled by an existing paradigm, not because it is flawed, but precisely because it *has* been successful.[47] For the emergent concept of spacepower, we need to view the situation from a different perspective, a new lens—a systems lens.

Twenty-first Century Strategy

The Systems Lens

Grand strategy as an all-encompassing consideration of power and its relationship to security must take a holistic approach to three things: elements, interconnections, and a purpose or ends. This fits the description of a system as described by Donella Meadows in *Thinking in Systems*, as "an interconnected set of elements that is coherently organized in a way that achieves something".[48] The elements in a strategy-focused system are what we notice most readily: nations, governments, military hardware, transport hubs, power generation

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[45] Sunzi and Griffith, *The Illustrated Art of War*, 106.
[46] Liddell Hart, *Strategy*, 339. Liddell Hart derided Clausewitz for his focus on the destruction of the enemy's forces. This unfair interpretation does not diminish the conclusion that war is more than victory in battles.
[47] Thomas S Kuhn, *The Structure of Scientific Revolutions* (Chicago, IL: University of Chicago Press, 1996), 1, 23.
[48] Donella H Meadows and Diana Wright, *Thinking in Systems: a Primer* (White River Junction, Vt.: Chelsea Green Pub., 2008), 11.

facilities, and so on. We can continue to broaden the view, or narrow it down, but either way the number of elements can be increased within any model. Unfortunately, we often believe that better fidelity in the description of a system leads to *comprehension,* whereas systems theory suggests the *interconnections* and relationships between the elements are the crucial component to comprehension.[49]

Systems thinking as it evolved from the 1950's came to epitomize a new paradigm of holistic thinking. In its formative years, a reductionist approach to describe systems in mathematical terms failed to solve problems, even though there was a belief that any *given problem* could be readily solved.[50] Proponents assumed that the system surrounding the problem was not problematic itself, that the world was mechanistic and linear, and applied forces or influences have a calculated, predictable outcome.[51] With such an approach, an expectation that rational analysis and mathematical projection would lead to consistent results was reasonable. However, the emerging theory that underlies the utility of modern systems thinking is that the world we are dealing with is complex, that the systems bounding our problems are actually indeterminate, and that we are unable to define the very problem in the first place. By accounting for a wide range of elements (physical and social), and their inter-relationships, a systems view leads to a journey of greater understanding of the problem rather than a headlong rush to solve it. Indeed, how can one solve what one doesn't actually conceive?

A Systems View of Strategy

A state's basic purpose to survive and, after satisfying this primary need, to thrive, is threatened by many emerging factors that were not of

[49] Dolman, *Pure Strategy*, 174.
[50] Peter Checkland, *Systems Thinking, Systems Practice: Includes a 30-year Retrospective.* (Chichester: John Wiley & Sons, 2005), A3.
[51] Bertalanffy cited in; Yacov Y. Haimes, *Risk Modeling, Assessment, and Management*, Wiley Series in System Engineering and Management (Wiley-Interscience, 2004), 18.

concern to earlier thinkers; globalization, cyber threats, weapons of mass destruction, resource scarcity, failing states, and climate change to name a few. Nonetheless, an ability to deter or win wars is obviously of enduring importance and stands alone as an essential role of the state. It is no wonder then that strategists seek enduring principles of strategic success.[52] The more that theory is based on an understanding of physical limitations, technology, and social and political systems, the greater the correlation for fitting theory to reality.[53] Strategy formulation undertaken using a scientific approach to finesse these factors is a worthy pursuit, an approach J.F.C. Fuller adopted in developing principles of warfare that still underpin many Western militaries today.[54]

With a scientific approach, an expectation that rational analysis and mathematical projection should lead to consistent results is a reasonable expectation. Nonetheless, strategy remains difficult. Thomas Kuhn contentiously proposed that normal science, the accumulation of knowledge to solve problems, was flawed if the problem lay outside the paradigmatic views of the scientist.[55] Although important, he contends that normal science, or "puzzle solving" would only take things so far.[56] Perhaps strategy is so often perceived as difficult because it comes from a flawed paradigm, one that lacks a holistic view of the elements of power and their relationship to the ends sought.

Systems thinking offers a scientific approach of looking at a holistic space strategy that is integral to the wider purview of grand strategy. Although scientific, it contrasts with the traditional science of

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[52] Stephen M. Walt, "The Search for a Science of Strategy: A Review Essay," *International Security* 12, no. 1 (July 1, 1987): 141.
[53] Walt, "The Search for a Science of Strategy: A Review Essay," 142.
[54] Fuller, *The Foundations of the Science of War*.
[55] Kuhn, *The Structure of Scientific Revolutions*.
[56] Kuhn, *The Structure of Scientific Revolutions*, 35–36; See also; James Gleick, *Chaos : Making a New Science* (New York, N.Y.: Penguin Books, 2008), 37; And also; Antoine J Bousquet, *The Scientific Way of Warfare: Order and Chaos on the Battlefields of Modernity* (New York: Columbia University Press, 2009), 21.

logic, mechanistic, and reductionist views, as characterized by Western thinking since the Industrial Revolution.[57] Systems thinking originated to provide explanatory power for biological systems, morphing to cover *gestalt* psychology and later used in quantum physics to explain the new principles of uncertainty.[58] As a paradigm change within these fields, it has revolutionized understanding and provided the basis for new theory. Increasingly, systems thinking is seen to have a place in strategy. Nonetheless, holism, intuition, and the vague notion of systems as a contrast to reductionist hard science presents a mental challenge for acceptance—it sounds almost mystical, more art than science.

Strategy viewed from the perspective of a Western, Clausewitzian approach attempts to link ends to means, but such a view has certain limitations, and the relationship is less than linear.[59] What are the ends a modern state is to achieve in a complex world? If the strategist is unable to see the larger picture, then the view may not provide the answer. In effect, the strategist may not see the wood for the trees—or more appropriately, the trees for the closer myopic view of the wood. If one is a surgeon, there is a tendency to see disease as something to cut out. The military professional may be similarly predisposed to see things in terms of force. Or, as succinctly stated by Abraham Maslow, "I suppose it is tempting, if the only tool you have is a hammer, to treat everything as if it were a nail."[60]

The utility of systems thinking applies across the full spectrum of war, including irregular warfare—Mao Tse Tung's writing on protracted war made it clear that "the source of all erroneous views on war lies in

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[57] Meadows and Wright, *Thinking in Systems*, 4.
[58] Fritjof Capra, *The Web of Life: a New Scientific Understanding of Living Systems* (New York, N.Y.: Anchor Books, 1997), 30.
[59] Alan Beyerchen, "Clausewitz, Nonlinearity, and the Unpredictability of War," *International Security* 17, no. 3 (Winter, 1992–1993) (1992): 68.
[60] Abraham Maslow, *The Psychology of Science: A Reconnaissance.*

the idealist and mechanistic tendencies on the question".[61] In accord with Mao, though referring to the other end of the warfighting spectrum, Colin Gray insists that holism is the right perspective for strategy with no room for reductionism.[62] At the operational level of airpower strategy, John Warden also viewed an enemy as a system, emphasizing bombing for systemic effect.[63] At the highest level, Dolman maintains it is the strategist's role to discern patterns from the broader view.[64] At all levels, the wise strategist understands a holistic view is necessary—what is needed is a theory of strategy for complex systems.

The recommendation to embrace uncertainty and complexity theory in strategy should not lead to a wholesale abandonment of conventional, predictable, and linear events. Once one accepts the systems approach, the manner in which analysis is constructed offers insight and understanding, opening up entirely new avenues of inquiry. Uncertainty theory has not led to the demise of physics, for example, it opened up a whole new discipline in which quantum theory is extending our understanding of the sub-atomic world and projecting ultra-fast computational capabilities. In biology also, systems thinking has led to major breakthroughs in agriculture, medicine, health, and other practical applications. The subtleties of systems thinking can, and have, outweighed the certainties of reductionist approaches.

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[61] Mao Tse-Tung and Samuel B Griffith, *On Guerrilla Warfare* (Urbana: University of Illinois Press, 2000), Para 8.

[62] Gray, *Explorations in Strategy*, 7. Balancing holistic inclusiveness against reductionist exclusivity is the main purpose of Gray's book. .

[63] John Warden, "The Enemy as a System," *Airpower Journal* no. Spring 1995 (n.d.), http://www.au.af.mil/au/cadre/aspj/airchronicles/apj/apj95/spr95_files/warden.htm.

[64] Dolman, *Pure Strategy*, 189.

Chapter 2

Strategy for Complex Systems

Exponential growth, interdependence, complexity, friction, interconnectedness, and other similar terminology area often used to describe the modern world system. How then can we develop strategy to cater to these abstract concepts? Gray suggests that the complexity of modern war and hence modern strategy is such that no great strategist of this century is likely to unify theory to the extent of a Clausewitz or Sun Tzu.[1] And although complex systems may be underpinned by simple rules, the multiple independent agents interacting in many ways ensures that the nature of such structures is indeterminate.[2] As Dolman summarizes, "complexity means that good strategy-making is *hard.* It is elusive. It rests on so many variables that the best we can hope for is an approximation."[3]

A method of approximation is needed, but in that case, modeling complexity is, well, complex. Traditional means fail to resolve problems, such as terrorism, environmental degradation, crime, or war, Horst Rittel and Melvin Webber appropriately describe these as "wicked problems".[4] They argued that science is unable to answer these wicked problems because every interest cannot be satisfied; someone's win must be somebody else's loss.

In his book *Simply Complexity*, Neil Johnson devotes a chapter to "war and complexity", making an argument that links war and complexity theory. War, he argues, is the most violent collective act of

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[1] Gray, *Modern Strategy*, 115.
[2] Morris Mitchell Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos* (New York: Simon & Schuster, 1992), 11.
[3] Dolman, *Pure Strategy*, 168.
[4] Horst W. Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," *Policy Sciences* no. 4 (1973): 160.

humans, where groups fight for advantage in a competition for resources. He makes the case that as this includes forms of power (social, economic, and political), then war exemplifies complexity in action.[5] Importantly, decisions made by groups of people in response to events have an effect on the system, and the system simultaneously influences decision-making—an effect called feedback, and this is another indicator of complex system behavior.[6]

Clausewitz's famous dialectic argument between the logical absurdities of unlimited force in theoretical war, versus the limiting factors of real war led to his thesis of war as a paradoxical trinity.[7] War in theory, or the abstract, tends towards *positive feedback*, where an act of force induces in an opponent a counterforce, and taken to its (theoretically absurd) conclusion leads to extremes.[8] A process of feedback can also be negative, reducing the effect of the outputs of a process. Feedback delineates non-linear behavior and, in systems theory, is a key component indicating system complexity.[9]

The distinction between linear and nonlinear is an important discriminator. A linear system exhibits a proportional response to an initial input. A visual example is a straight line on a graph, where the x output is consistently and predictably dependent on the y value. A nonlinear system is unpredictable, and may appear to be erratic and diverge quickly from previous values, or oscillate around a random path. The world is full of nonlinearity, but we tend to think of these examples as aberrations. Clausewitz, as a strategist, understood this characteristic

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[5] Neil F Johnson, *Two's Company, Three Is Complexity: a Simple Guide to the Science of All Sciences* (Oxford: Oneworld, 2007), 160, 161.
[6] Johnson, *Two's Company, Three Is Complexity*, 163.
[7] Clausewitz et al., *On War*, 89.
[8] Clausewitz et al., *On War*, 77 & 88; Donella H Meadows, Jørgen Randers, and Dennis L Meadows, *The Limits to Growth: The 30-year Update* (White River Junction (Vt): Chelsea Green, 2004), 26. Meadows, et al, surmises that violence may be inherently exponential, a view closely aligned with Clausewitz.
[9] Johnson, *Two's Company, Three Is Complexity*, 13.

within conflict intuitively, and thus Alan Beyerchen in a paper on "Clausewitz, Nonlinearity, and War," concludes that our ability to predict outcomes when it comes to conflict is severely limited.[10] It is this element of Clausewitz that preserves his enduring utility for modern strategy, and provides the rationale for linking strategy to the concept of complexity.

But what is the value of linking grand strategy to complexity? The similarities are clear; both have multiple elements interacting in some sort of system. In complex systems, a full understanding of each constituent element (the reductionist approach) is not required in order to understand what a combination of elements might do.[11] Extrapolating this to grand strategy, we can infer that an understanding of spacepower as a system can provide greater, more useful explanatory power than a narrower understanding of just the individual elements within the system. A system view of spacepower therefore explains how it fits within grand strategy by revealing the connections to other important elements. A reductionist view, which has a tendency to only consider satellites as individual capabilities within their own right, is less useful as it cultivates the wrong message about the importance of spacepower.

Exponential Growth and Strategy

Picture a piece of paper and mentally fold it in half. For an average piece of paper one tenth of a millimeter thick, this doubles its thickness to two tenths of a millimeter. Fold it again making it four times thicker; then again, making it eight times thicker; and so on, until forty-two folds later, the thickness of the paper is sufficient to broach the distance between the earth and the moon 378,000 kilometers away. This type of growth is termed exponential, and it surprises us because the numbers increase slowly at first, then so rapidly that it defies human

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[10] Beyerchen, "Clausewitz, Nonlinearity, and the Unpredictability of War," 61.
[11] Johnson, *Two's Company, Three Is Complexity*, 17.

comprehension.[12] Mathematically, we can express the relationship simply, but the unassuming equation belies its often-astonishing result. If a mathematical expression is available, then does it often astonish?

We are witnesses to the tangible effect of exponential growth in many areas. The hunter gatherer societies which lasted tens of thousands of years were followed by the agricultural age lasting thousands of years, the industrial age for hundreds of years, and we find ourselves now in a new information and space age, which may only last decades if it follows the exponential growth patterns of previous eras.[13] Meadows and others argue that systems such as population and productive capital in human society are on an exponential trajectory until a limit is reached, which typically leads to cataclysmic failure in the growing system.[14] Ray Kurzweil, in his futuristic projection of sentience in *The Age of Spiritual Machines,* also adopts a view of exponential growth but suggests that humankind's ability to innovate overrides any natural limits to growth.[15] Whether we are headed for a Malthusian collapse or a new era of abundance, the message is the same—the effect of exponential growth in a system is difficult to comprehend, rarely predictive in the real world, and in these instances, makes the derivation of strategy hit and miss.

Risk and Strategy

Given the increased complexity of security issues arising in the twenty-first century, there is little prospect that military force *by itself* can negate threats in the same way it has dealt with conventional, less

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[12] Meadows, Randers, and Meadows, *The Limits to Growth*, 6.
[13] Waldrop, *Complexity*, 15.
[14] Meadows, Randers, and Meadows, *The Limits to Growth*, 27.
[15] Ray Kurzweil, *The Age of Spiritual Machines When Computers Exceed Human Intelligence* (New York; London; Victoria: Penguin Books, 2000), 34–35; Also see Peter H Diamandis and Steven Kotler, *Abundance: The Future Is Better Than You Think* (New York: Free Press, 2012).

complex scenarios.[16] Risk assessment and management, with its origins in economics, engineering, and business, has emerged as a distinct field of study with a wide variety of applications to determine how to efficiently mitigate undesired scenarios. While risk assessment and management aligns well with the holistic view of systems thinking, it is not integrated into our formal education and management processes.[17] In the national security arena, application of risk management concepts offer one way to address these wicked problems, and the limited work to date in this area confirms the field is ripe for the picking.[18]

Risk, as the product of likelihood and consequence is a useful tool that is only beginning to be properly applied in the national security environment.[19] For example, the U.S. Government Accountability Office released a risk management report in December 2005 that emphasized government pressure to apply risk management procedures in homeland defense.[20] Much of the literature on risk as it pertains to security deals with the tactical or operational level of risk, largely because of the complexity involved, and the difficulties in modeling the system.[21] Practically speaking, risk management applied to complex systems and its impact on strategy might prove to be of little actual use. There is still much to be said for Clausewitz's appreciation of the genius commander's

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[16] Nathan Freier and Army War College (U.S.). Strategic Studies Institute., *Toward a Risk Management Defense Strategy* (Carlisle, Pa.: U.S. Peacekeeping and Stability Operations Institute: Strategic Studies Institute, 2009), 11, http://purl.access.gpo.gov/GPO/LPS116387.
[17] Haimes, *Risk Modeling, Assessment, and Management*, 18–21.
[18] Paul J Bracken, Ian Bremmer, and David Gordon, *Managing Strategic Surprise : Lessons from Risk Management and Risk Assessment* (Cambridge, UK; New York: Cambridge University Press, 2008), 1.
[19] Ian Bremmer and Preston Keat, *The Fat Tail: The Power of Political Knowledge for Strategic Investing* (New York: Oxford University Press, 2009), 52.
[20] US Government Accountability Office, *Risk Management, Further Refinements Needed to Assess Risks and Prioritize Protective Measures at Ports and Other Critical Infrastructure*, December 2005, http://www.gao.gov/cgi-bin/getrpt?GAO-06-91.
[21] Haimes, *Risk Modeling, Assessment, and Management*, 690. .

coup d'oeil—whereby intellect alone can derive the truth.[22] An understanding of limitations inherent in risk management, however, is still worth pursuing.

Risk means many things to different people, and is often misunderstood as only the *probability* of an undesired event, such as the probability of being involved in a terrorist attack, or the probability of losing something valuable (such as personal freedom or life itself). Again, this offers little practical value in dealing with complexity or strategy. The natural human tendency is to conflate risk perception and try to avoid any life-threatening event (such as war), no matter how small the probability. Ian Langford's investigation on the social risk perception in response to existential (life threatening) threats supports the view that human perception of risk is skewed in these scenarios.[23] If applied to mitigation strategies, the probabilistic notion of risk leads to inefficient mitigation strategies and poor strategy.

The measure of risk that aligns with the science of risk management is that risk is some combination of both probability (or likelihood) *and* consequence.[24] Mathematically expressed; risk = f (probability, consequence). Often, risk is plotted on a graph as a combination of these factors and this provides a visual or graphical representation that instantly highlights where perceived risk lies. This calculation effectively equates adverse events of high consequence and low probability with events of low consequence and high probability.[25] Based on this method, it seems reasonable to expect that the science of risk management should account equally for the highly improbable but high consequence event, as it does for highly probable.

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[22] Clausewitz et al., *On War*, 102.
[23] Ian H Langford, "An Existential Approach to Risk Perception" (Centre for Social and Economic Research on the Global Environment School of Environmental Sciences University of East Anglia and University College London, 2001), 4–8, 26–27.
[24] Haimes, *Risk Modeling, Assessment, and Management*, 32.
[25] Haimes, *Risk Modeling, Assessment, and Management*, 29.

Figure 1 is a generic risk hazard matrix that typifies this kind of analysis. It demonstrates the point made earlier that a highly improbable (rare) event, if it has severe consequences, could be considered a high (but not extreme) risk. The terminology differs between disciplines and approaches, but the risk hazard approach is consistent across disciplines. For example, military standard 882 (MIL-STD-882D) uses a similar matrix model, and similar terms for probability: frequent, probable, occasional, remote, and improbable. Similarly for severity: catastrophic, critical, marginal and negligible.[26]

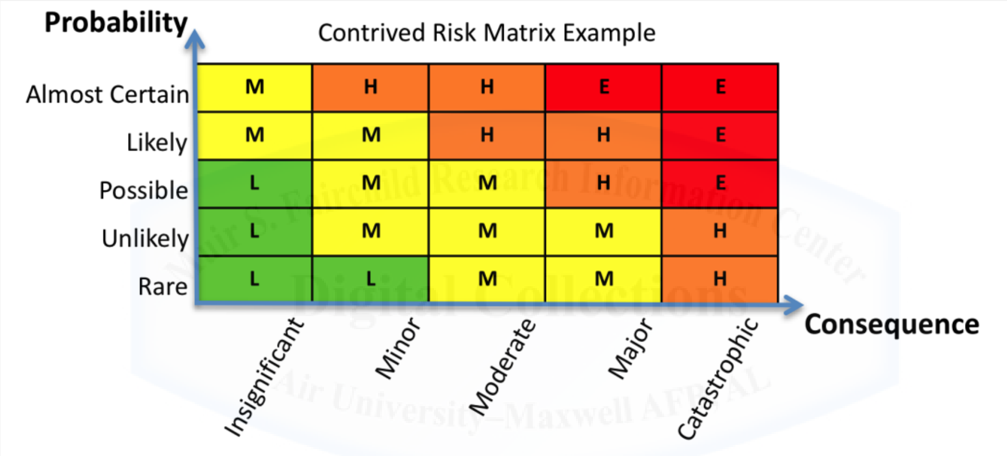

Figure 1: Example Risk Matrix

Source: Author's original work.

The conventional risk hazard matrix expressed less descriptively, as in Figure 1, and purely mathematically as a multiplication of both probability and consequence is shown as Figure 2 below. Figure 2 reveals that risk magnitude radiates out from the top right corner, and also demonstrates that highly improbable but high consequence (bottom row) events are diluted as a priority.

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[26] Department of Defense, "Standard Practice for System Safety, MIL-STD-882D," February 10, 2000, Appendix A, https://acc.dau.mil/adl/en-US/255833/file/40632/MIL-STD-882D.pdf.

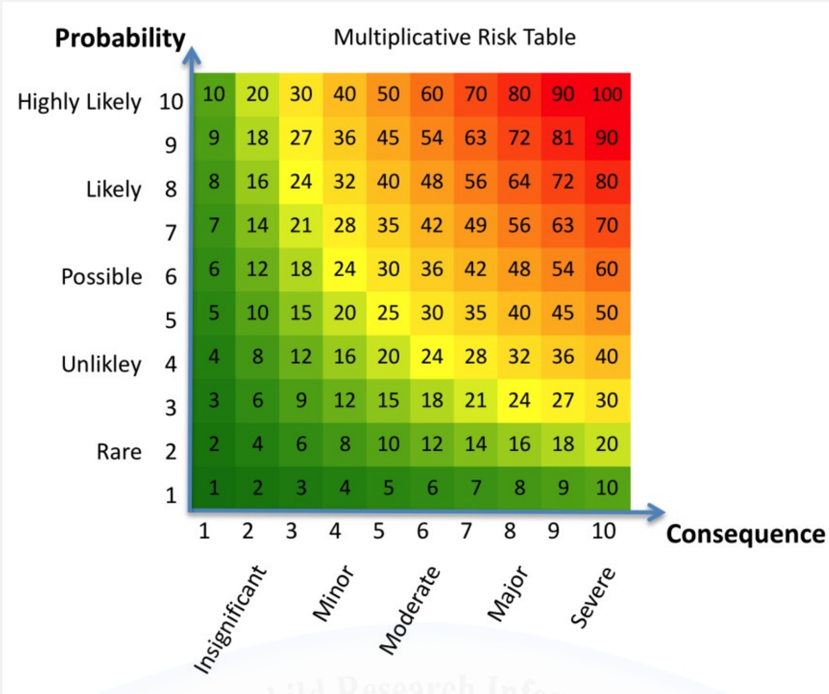

Figure 2: Mathematically Derived Risk Matrix

Source: Author's original work.

In the case of probabilistic bias of risk described earlier, the value of consequence is biased, such that risk = (probability) x (gain x consequence). The gain is a factor of importance that weights consequence more than probability. The graph at Figure 2 demonstrates this visually. From the discussion of military force earlier, we can see that a realist view of the world proposing that war between states has significant consequence (remember the ultimate purpose of the state) means that risk associated with war is always considered to be high. The effect of a realist bias is that a strong military as insurance against war *is always justified.* A realist bias ensures that action is taken for any risk associated with a high consequence, but the negative aspect of such a view is that resources for risk mitigation will also be biased towards the high consequence—a response that is neither sophisticated nor

considerate of a grand strategic view and the competing demands of statehood.[27]

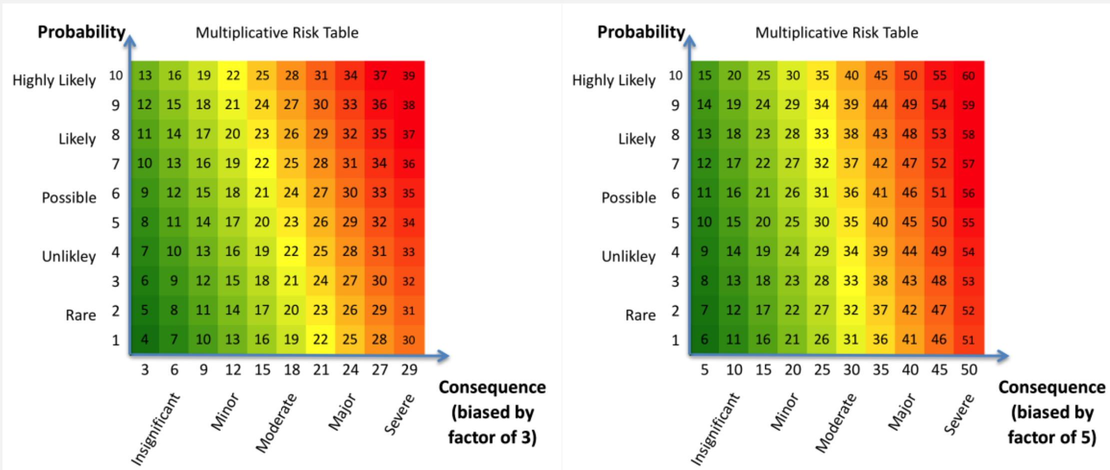

Figure 3: Consequence Bias x 3 and x 5

Source: Author's original work.

The observation of risk as a function of probability and consequence in a typical risk hazard matrix demonstrates that the highly improbable but high consequence event is diluted as a priority. Conversely, if consequence is weighted, as it is in a realist paradigm, probability becomes irrelevant. The risk hazard model appears to portray a nonlinear relationship between elements in different scenarios, and once again raises the dimension of system complexity. An alternative model is needed to cater for the highly improbable but nonetheless highly consequential event. Such a model would account for the calamitous events that appear throughout history such as: famine, natural disaster, critical system collapse, and war; but nonetheless have no consistent basis for a mitigated response.

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[27] Robert Jervis, *Perception and Misperception in International Politics* (Princeton, N.J.: Princeton University Press, 1976), 424. Jervis concludes that the cost of overestimating hostility is itself often underestimated.

The analytical risk hazard model should, according to the theory, highlight the consequences of adverse scenarios, and provide a measure to indicate where resources should be applied. It falls short in two areas. First, as described in the preceding paragraph it does not appear to cater for highly improbable but highly consequential events, and second, because it addresses risk through mitigation of *perceived* events. Our human ability to understand complex systems, especially when time stressed or time constrained, is poor; and this ensures that unidentified or unforeseen risks are not addressed under the model.[28]

Improbable Calamity

We expend a great deal of effort mitigating the risk of losing state sovereignty through war, based on a realist outlook that such war, however improbable, is nonetheless phenomenally consequential and ruinous. Yet, we tend to overrate our expertise in defining and mitigating risk, whilst compounding the problem by underrating the possibility of highly improbable events.

Nassib Nicholas Taleb examines our inability to understand highly improbable events in his book *The Black Swan.* He laments the *average* persons conceit that instills a belief that we can predict events, and suggests that not only is this flawed, it also indicates that we do not even understand how this is flawed—understanding is beyond a conceptual grasp of the problem.[29] Consequently, he considers the mathematics, and attacks the conventional notion of probability determination based on normal distribution curves by offering up a theory that effectively negates the accuracy of conventional risk management—but only in the area of the highly improbable. Yacov Haimes, a leading figure in risk

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[28] Dietrich Dörner, *The Logic of Failure Recognizing and Avoiding Error in Complex Situations* (Cambridge (Mass.): Perseus Books, 1996), 185–199.
[29] Nassim Taleb, *The Black Swan: The Impact of the Highly Improbable* (New York: Random House, 2007), xx, 140.

management highlights the problem of extreme events also, but maintains a risk hazard approach.[30] Probability, based on human perception, and the determination of consequence in complex systems remains inadequately addressed in the multiplicative method described earlier.

A poor understanding of the highly improbable can be damaging in another way. Not only might it lead to a diminished consideration or to no consideration, it can work in the other direction by overinflating perceptions of risk at the expense of other more critical system events. Terrorists provide a classic example, where the number of casualties due to terrorism is given disproportionate weighting because of their perceived immediacy. Gruesome images and frequent media reporting induce what Daniel Kahneman in *Thinking Fast and Slow* calls an "availability cascade" that distorts priorities in the allocation of public resources.[31] Although Kahneman writes on human perception (thinking fast) versus objective analysis (thinking slow), his insights are especially relevant for the space system. Space is easily overlooked due to other claims for attention, and protective actions tend only to be as good as the worst disaster actually experienced—in space this was the collision between a US *Iridium* satellite and the defunct Russian *Cosmos* satellite in February 2009.[32]

Dietrich Dörner, a scientist respected in the field of cognitive behavior suggests that by expecting the unexpected, we are better equipped to cope with the unknown, as opposed to laying extensive

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[30] Haimes, *Risk Modeling, Assessment, and Management*, 41, 470.
[31] Daniel Kahneman, *Thinking, Fast and Slow* (New York: Farrar, Straus and Giroux, 2011), 144.
[32] Kunreuther cited in; Kahneman, *Thinking, Fast and Slow*, 137; Cesar Jaramillo, ed., *Space Security 2011* (Pandora Press, Kitchener, Ontario, 2011), 8–9, http://www.spacesecurity.org/space.security.2011.revised.pdf.

plans, and believing that this will eliminate the unexpected.[33] If insecurity leads to precise planning (the classic military approach), which reveals greater risks and hence greater insecurity, even more precise planning ensues—leading to a vicious circle and potentially disastrous outcomes.

Resilience and Strategy

The deficiencies highlighted in risk management for the improbable but consequential event is illuminating, as it touches on the many concerns raised already—how do we develop national security strategy (an attempt to match means to ends), in a complex world (the epitome of a large complex system), and adequately address the threat to our most critical systems? One approach is to expect the unexpected, to "embrace chaos", and in so doing, plan in a manner that diminishes the effect of surprise such that the system is not critically injured and is able to recover.[34] In other words, we should stop trying to forego pain—and instead accept its potential and design our systems to be resilient.

Acceptance of pain, or loss, is inimical to the way society is presently structured. As a society, we are risk averse, and seek to punish those leaders on whose watch the loss occurred. Our traditional focus for strategy, as noted by Bernard Brodie, bears many similarities to the problems of economics—both are concerned with the efficient use of resources to achieve ends.[35] Efficiency is fine when optimizing a system for a given output, with predictable inputs, and a benign external environment; but not useful for the highly improbable, or purposefully destructive.

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[33] Dörner, *The Logic of Failure Recognizing and Avoiding Error in Complex Situations*, 164–165.
[34] Bousquet, *The Scientific Way of Warfare*, 34, 233; Colin S. Gray, "The 21st Century Security Environment and the Future of War," *Parameters* no. 2008 Winter (n.d.): 16.
[35] Bernard Brodie, *Strategy in the Missile Age* (Santa Monica, CA: Rand Corp., 2007), 361.

There are, of course, potential advantages a tightly coupled complex system has when responding to disruption. Modern society as a whole responds to epidemics, fires, and adverse situations much better than their mediaeval counterparts, though it might be more accurate to suggest that *capacity* has increased, in response to efficient design. A large city with good government collects resources from the population in order to efficiently provide medical, emergency, and other services. Scaling the concept upwards, we see the foundation of modern social contract theory as espoused by Jean-Jacques Rousseau, whereby society gives up some of its rights in order to improve the conditions of society as a whole—and in so doing, provides the necessary elements for a view of grand strategy.[36]

A tightly coupled, well-designed system as described is a paragon of efficiency. While the system operates within its design capacity, its output may be considerably more than its less coupled, less optimized predecessors. However, when the design capacity is exceeded, failure usually occurs—not gracefully, but catastrophically. To bolster the reliability and survivability of artificial systems, designers intuitively cater for abnormal situations. This may manifest as increased material strength (think of exotic alloys), extra material (possibly greater thicknesses or heft), or replaceable parts—for example. In engineering terms, the usual measure describing the increase is called a *factor of safety*.

Factor of safety is a numeric value indicating the increased structural strength of a designed component above its required load. In aerospace engineering, a typical safety factor used in the design of critical components is three to five per cent. As weight is such a critical factor in aircraft performance, a *marginal* allowance of error is calculated

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[36] Celeste Friend, "Social Contract Theory," *Internet Encyclopedia of Philosophy* (2004), http://www.iep.utm.edu/soc-cont/#SH2c.

before the system (by design) catastrophically fails. Conversely, in civil engineering, where performance due to weight is less critical, factors of safety can be in the order of two to three *hundred* per cent—a concrete building built in this way will stand the test of time. By analogy, as society as a system has become more complex, more interdependent, and tightly coupled—then the inherent factor of safety may be slowly eroding, not by design, but as a consequence of improved efficiency. If the system subsequently fails, it fails in a spectacularly catastrophic manner.[37]

The risk mitigation approach as described earlier, widely used in industry, and increasingly in government and the military, does not adequately address the highly improbable, and is certainly ill-designed to counter the intentional threat generated by conflict and war. As Clausewitz relates, war is not an exercise of the will directed against inanimate matter, but is directed against animated objects that react—improbably, and unknowingly. And, it is the highly improbable, the extreme, and the unknown that dominates our world, and will increasingly do so.[38]

To understand grand strategy for the twenty first century, systems thinking provides a useful lens to conceptualize the influence of complexity and conflict. I propose that national security addressing complex systems needs to be approached in two ways: first, through risk mitigation practice to alleviate risk against conceivable threats; and second, through directed improvements in resilience at key nodes or centers of gravity based on a system analysis. It is the latter area that will be addressed for the space system, to view dependency and response to it in a different, less conventional light.

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[37] Louise K Comfort, Arjen Boin, and Chris C Demchak, *Designing Resilience: Preparing for Extreme Events* (Pittsburgh, Pa.: University of Pittsburgh Press, 2010), 6.
[38] Taleb, *The Black Swan*, xxvii.

Chapter 3

Spacepower Theory

A consistent theory linking grand strategy down to military action that best incorporates spacepower can be synthesized from Dolman's analysis in *Pure Strategy*. Contrasted with Clausewitz's focus on war as a duel to compel an opponent in decisive battle, Dolman argues that strategy is a plan for ongoing advantage, not just a culmination or victory.[1] Spacepower and strategy alike derive from national interests or in response to threats to those interests.[2] Therefore, spacepower is not a self-serving goal to have the strongest, most capable force possible—it is subject to the same political ends that drive grand strategy.

At present, spacepower theory is confusing. The arguments, policies, and discussion around spacepower have been discordant, and too often ideology is confused with strategy. The paradox of space stems from the strongly conflicting views of realists who argue that the ability to project force into space supports peace, versus the liberalists who eschew military force—ostensibly to also support peace. Ends converge, but the means are different, thus the confusion.

The confusion extends to definitions. In national security and space related discussions, the concept of spacepower is often not used, and if it is, a consistent definition is harder to come by. There is no singular reason or simple explanation for why this is so—though perhaps a desire to remain distant from the perceived negative (warlike) connotation of spacepower is reason enough. Thus, although the US approach to security is holistic and recognizes the complex nature of the problem, neither the *National Space Policy of the United States of America*, nor the US *National Security Space Strategy* refers to

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[1] Dolman, *Pure Strategy*, 5–6, 33.
[2] Dolman, *Pure Strategy*, 146; McDougall, *The Heavens and the Earth*, 91.

spacepower as a singular concept.[3] US doctrinal publications such as *Joint Publication 3-14, Joint Doctrine for Space Operations,* concepts tend to be prescriptive and are focused on the operational (vice strategic) level of war.

John Sheldon and Colin Gray in the February 2011 compilation of essays titled *Toward a Theory of Spacepower* suggest that a strategic theory for spacepower is still lacking due to the following reasons:[4]

- a limited history,
- confused definitions,
- extensive secrecy,
- tales of derring-do,
- portrayal in popular culture,
- complexity,
- linear thinking,
- technological determinism,
- little understanding of orbitology, and
- space is out of sight, out of mind.

Similar themes evolve in the space system model developed later, and the notions of complexity and linear thinking will support a complex systems view. To account for a limited history, several theories tend to apply analogous logic from other domains such as air and maritime. Nevertheless, though a maritime analogy is of greatest use, neither air nor maritime strategies provide a good strategic framework from which to

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[3] "National Space Policy of the United States of America," June 28, 2010, http://www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf; DOD, "National Security Space Strategy -Unclassified Summary," January 2011, http://www.dni.gov/reports/2011_nationalsecurityspacestrategy.pdf.

[4] John B. Sheldon and Colin S. Gray, Theory Ascendant? Spacepower and the Challenge of Strategic Theory, in Charles Lutes and Peter Hays, eds., *Toward a Theory of Spacepower* (Washington, D.C.: National Defense University Press, 2011), 1,2.

begin.[5] Strategist Herman Kahn in 1969 goes further, contending that the notion of control of space, even as an analogy for air or sea is "completely misleading for space."[6] Notwithstanding the above admonishment, a look at other definitions of military power illuminates the goal of defining spacepower.

Distinct From Land, Sea, And Air

Clausewitz said, "the primary purpose of any theory is to clarify concepts and ideas."[7] These concepts and ideas can become general principles, guides and axioms for their use in strategy—the application of means to achieve political ends. Coming from a military context, Clausewitz's definition is certainly applicable to military power. Land power theory, derived from thousands of years of conflict, is well established in the theoretical works of Clausewitz, Sun Tzu, J.F.C. Fuller, and others who have provided fundamental principles. Seapower has had similar consideration through the writings of Mahan and Corbett. Douhet and Mitchell provided visionary aspirations for airpower, which have since been translated by modern strategists such as John Slessor, John Warden, Colin Gray and John Boyd to provide another set of principles distinct from land and sea. Spacepower suffers from a paucity of thought such that an agreed set of principles is lacking. Although spacepower has many similar principles to seapower, and is half the age of airpower, principles have not been drawn from a crucible of conflict as they have with the other forms.

A definition of power with the domain as its central tenet reads as: an ability to—control/regulate/influence—in, or from the domain. Its

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[5] Klein, *Space Warfare*, 20.
[6] Herman Kahn, On Thermonuclear War, 486, cited in James Clay Moltz, *The Politics of Space Security: Strategic Restraint and the Pursuit of National Interests* (Stanford (Calif.): Stanford Security Studies, 2008), 19.
[7] Clausewitz et al., *On War*, 132.

highest purpose, as an effect, is to deny access to the domain.[8] Using the domains of sea, land, air and space in the context of military power is one way to provide a basis for theory. Nonetheless, and while it has many heuristic benefits, analogy always breaks down when subject to deeper analysis. To be useful, an essential aspect for comparison is an understanding of their various characteristics in relation to each other, and this will be done in each of the analyses that follow.

Land

The land domain is characterized by operations on the surface of the earth, between nation states and their abutting borders. Clausewitz's interpretation of military power can be considered as a template for land power. He had no consideration of sea power in *On War,* and air, space, and cyber power did not exist in the abstract or in reality. Nonetheless, Clausewitz established *enduring* themes applicable to all forms of power. Key amongst his many arguments is his analysis between war in theory and real war. Theoretical war is an abstraction, a fantasy that leads to extremes, and although possible—is not the type of war that occurs between states in practice. Real war is influenced by three elements: violent emotion; chance and probability; and politics (or reason).[9] Space war will also be subject to the irrational forces of violent emotion and uncertainty, and also constrained by rational reason.

Sea

The sea domain is as restricted to two-dimensional movement as is land, both constituting the surface of the Earth. Julian Corbett argued that the unique characteristic of sea power was its ability to appear as if from nowhere, as a fleet once sailed from port was effectively invisible,

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[8] Dolman, *Pure Strategy*, 32–35.
[9] Clausewitz et al., *On War*, 89.

providing a dimension of surprise and omnipresent threat.[10] This; however, is no longer valid, as the fleet can now be seen from the air and space, and thus its relatively slow moving effect can be deduced geographically at least. Though the analogy of being lost from view no longer applies to seapower, it becomes useful for space in specific contexts. Satellites in orbit, like their sea-bound counterparts require regular observation to fix and predict their next position, otherwise they are quickly lost in their environment.

Seapower is also unique (from land) in that it operates outside the legal bounds of nation states. International waters begin 12 nm from national sovereign territory and constitute a domain subject to international law. From the structural realist perspective of Waltz, whereby the international system is in anarchy, the law of the sea might read as "might makes right." Spacepower, too, operates in international no-man's land, but has the added complexity of simultaneously operating above nation states. The foundation to be accepted is that international norms and behavior need to be also applied to spacepower, deterrence must be backed by force and intent, and regimes are important.

Air

Operating in the third-dimension of air, aircraft may move much faster than ships or land vehicles, but the advantage is offset by a unique cost. Heavier-than-air aircraft must rely on constant motion in order to remain aloft. The contrast to the land and sea domain is stark. Ships or submarines rely on buoyant forces and this both reduces propulsive costs and negates the requirement for constant movement. An aircraft carrier, for example, can remain on operations at low or no speed. Similarly, tanks, trucks and soldiers all placed on solid earth remain in

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[10] Julian Stafford Corbett, *Some Principles of Maritime Strategy* (Annapolis, Md.: Naval Institute Press, 1988), 158.

place without any propulsive cost. However, aircraft must continuously consume fuel to remain in their domain. Contrasted with the space domain, satellites in orbit require propulsion only for station keeping (minor movement) or to effect a radical change in position.

Taking an airpower analogy for spacepower further has utility as a starting point for characterizing spacepower's strengths and weaknesses. Drawing from Colin Gray's discussion of the characteristics of airpower, spacepower shares many key characteristics, including ubiquity, range and reach, speed of passage, and geographically unrestrained routing—though with one critical caveat.[11] The elements in orbit (satellites) are unrestrained geographically, but orbital mechanics dictate that their paths are energy constrained. This is analogous to a highway network through mountainous terrain facilitating high-speed access enroute, whereas departure from the highway demands extra fuel and power to forge a new path.

Cyberspace

Cyberspace is not intuitively understood as a domain in the physical sense. Unlike land, sea, and airpower; spacepower and cyberpower are largely complementary and indirect, lacking a sense of coercive power.[12] However, although indirect and virtual in nature, there is overwhelming evidence supporting the view that cyberspace is growing in consequence for any modern, post industrialized, trading nation state.[13] The biggest change according to Richard Clarke is that cyberspace increases remote access to physical systems.[14] Taken to an

[11] Gray, *Explorations in Strategy*, 68.
[12] John B Sheldon, "Deciphering Cyberpower: Strategic Purpose in Peace and War," *Strategic Studies Quarterly* (Summer 2011): 99.
[13] David J Lonsdale, *The Nature of War in the Information Age: Clausewitzian Future* (Portland, OR: Frank Cass, 2004), x, Chapters 6 & 8, and Appendix A.
[14] Richard A Clarke and Robert K Knake, *Cyber War : The Next Threat to National Security and What to Do About It.* (New York: ECCO Press, 2010).

extreme, Chris Demchak argues this effectively negates the normal dampers on hostility and requires a new theory of war.[15] Thus, activity in cyberspace provides a measure of stealth and anonymity, and the difficulty of monitoring and policing cyberspace underpins concerns about attribution, which negates normal deterrence behavior.

The space system is also at risk from this less than optimal deterrent situation for two reasons. First, space systems rely heavily upon cyberspace for its connectivity to the world and other systems, thereby inheriting cyberspace's weakness. Furthermore, space systems in orbit are far more vulnerable to forms of stealthy attack due to their lack of sensing systems that are able to categorize such attacks. Unlike their human occupied terrestrial vehicular counterparts, an attack might not be attributable—a situation that presents itself as being similar to cyberspace.

While the analogous characteristics of land, sea, air, space, and cyber power have not been exhausted here, the relevant ones for understanding the nature of spacepower in the following definition have been addressed.

Spacepower Defined

Airpower and spacepower produce very different effects in their ultimate expression as an instrument of force. The fundamental principle of airpower, its defining purpose, is to impose an effect in the air to contest and control the domain. Success in this is the precursor to other uses of airpower; such as the delivery of kinetic energy to the earth's surface to destroy selected targets, or to enable non-kinetic effect such as information gathering. Similarly for land and seapower, their definitive purpose is to dominate their respective domain through the use of, or the

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[15] Chris C Demchak, *Wars of Disruption and Resilience : Cybered Conflict, Power, and National Security* (Athens: University of Georgia Press, 2011), 6.

threat of force. Paradoxically, although space and cyberpower are essential requirements for the application of military force today, they presently do not impose effects to contest and control their domains. They have not needed to as yet.

Australian doctrine declares: “Airpower is the ability to create or enable the creation of effects by or from platforms using the atmosphere for maneuver.”[16] This platform-centric definition is consistent with the way Australia tends to view airpower, and emphasizes the geography of the domain—the atmosphere. It works, but its narrow linear construct does not support a systems view of space.[17] It pays to heed Benjamin Lambeth, who cautions that airpower is not just hardware; it is a “complex amalgam” of many factors.[18]

A definition of spacepower with the domain as its central tenet reads rather similarly: an ability to—control/regulate/influence—in, or from space. A broader definition encapsulates the physical (or resource) aspects of space and the behavioral, borrowing from the contextual model used by Joseph Nye to describe power, and his extension of this to define cyberpower.[19] In this context, *spacepower is a measure of a nation’s ability to influence all operational environments and all instruments of power using the space system*. *Measure* is needed to understand the magnitude and provide a reference. *Nation* connotes the international political aspect of power and seats it in its rightful place. *Influence all … environments … and power* expands a traditional view (looking in) of power to affect, control, deny a domain (air, sea, land) and reverses the view (looking out) for an ability to affect reality outside of its

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[16] Australia. Royal Australian Air Force. Air Power Development Centre., *The Air Power Manual* (Tuggeranong, A.C.T.: Air Power Development Centre, 2007), 3.
[17] Lambakis, *On the Edge of Earth*, 45.
[18] Benjamin S Lambeth, *The Transformation of American Air Power* (Ithaca, N.Y.: Cornell University Press, 2000), 9.
[19] Nye, *The Future of Power: Its Changing Nature and Use in the Twenty-First Century.*, 122–123.

own domain. *Space system* encapsulates the wider concept of space capabilities as a system, not just the platforms or their weaponry. Thus spacepower, like airpower, is able to exploit its domain in order to influence the wider strategic environment.

The Purpose of Spacepower

The link can now be made between grand strategy and spacepower. From grand strategy, the strategist must apply the means available to achieve the desired political ends. Spacepower, distinct from airpower, seapower, landpower, and cyberpower, is but one potential means at the strategists' disposal. According to Dolman, this uniqueness lies at the crux of what purpose spacepower serves to its master.[20] To the extent that spacepower is subordinate to military power—itself subordinate to national power—the strategist must *ultimately* be able to employ spacepower (an ability to influence all operational environments and all instruments of power using the space system) to forcibly achieve an aim.

[20] Dolman, *Pure Strategy*, 30.

Chapter 4

Framing Spacepower

The previous chapter accepted that the primary purpose of theory is to clarify concepts and ideas, which *might* then become principles, guides, and axioms for use in strategy.[1] This is not to say that theory is prescriptive. The main purpose of developing theories of strategy is to highlight what needs thinking about—to provide insight, not answers.[2] The following chapter does not purport to develop a comprehensive spacepower strategy for Australia. Instead, it builds on the concepts of holistic strategy as it applies to complex systems, to highlight *what needs thinking about.* For detailed discussions on *how* to protect interests in an increasingly congested and contested space domain, one need only refer to a relatively small but eminent selection of works such as: John Klein's *Space Warfare: Strategy Principles and Policy,* Everett Dolman's *Astropolitik,* and James Moltz's *The Politics of Space Security: Strategic Restraint and the Pursuit of National Interests.*[3]

Systems theory applied to warfare has special relevance to airpower, and as later shown, to spacepower. As an instrument of war, airpower's potential when applied to key nodes has resonated with theorists since Giulio Douhet, who in 1921 postulated that the "most difficult and delicate task in aerial warfare" was selecting objectives, the grouping of zones, and the order in which they are to be destroyed.[4]

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[1] Clausewitz et al., *On War*, 132.
[2] Gray, *Modern Strategy*, 128; Osinga, *Science, Strategy and War the Strategic Theory of John Boyd*, 12.
[3] Klein, *Space Warfare*; Everett C Dolman, *Astropolitik: Classical Geopolitics in the Space Age* (London; Portland, OR: Frank Cass, 2002); Moltz, *The Politics of Space Security*.
[4] Giulio Douhet et al., *The Command of the Air* (Tuscaloosa, AL: University of Alabama Press, 1998), 50; Gray, *Modern Strategy*, 233. Gray concurs, airpower as an instrument of war has its tactical promise manifested in the choice of targeting.

Airpower then, and now, promised the military practitioner the holy grail of warfare, decisive victory, manifested through the targeting and destruction of key nodes as derived through systems thinking and analysis. Society then, as now, was perceived to be complex and fragile, and models of the system were developed to draw out the vital points. Variously known as *industrial fabric* theory or *industrial web* theory, they were applied via the bombing campaigns throughout World War II—with contentious results.[5] Much destruction was levied in the name of industrial web theory, but the capabilities to destroy the key nodes were perceived to be far greater than actuality. Means did not match the ends.

The systems theory thread has nonetheless traced its way through airpower theory and remains today. It is manifested as effects based operations, seen in targets system analysis, and has formed doctrine as seen in Warden's description of *The Enemy as a System*.[6] Airpower has achieved dramatic results when underpinned by systems thinking, but so have Special Forces operations, cyber-attacks, and many other military operations. The critical conclusion to be made is that systems analysis forms an important component of modern military planning and has been validated through practical applications. Additionally, many of the techniques and lessons have now been applied to understand and protect critical infrastructure in society, systems such as power, telecommunications, energy, banking and finance, and water.[7] So what about the space system?

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[5] Tami Davis Biddle, *Rhetoric and Reality in Air Warfare: The Evolution of British and American Ideas About Strategic Bombing, 1914-1945* (Princeton, N.J.: Princeton University Press, 2002), 162–164.
[6] Warden, "The Enemy as a System."
[7] "National Infrastructure Protection Plan," 2009, http://www.dhs.gov/xlibrary/assets/NIPP_Plan.pdf; "Critical Infrastructure Resilience Strategy" (Australian Government, 2010), http://www.ag.gov.au/Documents/Australian%20Government%20s%20Critical%20Infrastructure%20Resilience%20Strategy.PDF.

Systems Analysis Methodology

Despite a wealth of literature on systems theory, the practical application of systems thinking is frequently overlooked, or is too esoteric to be described. Still, the range of approaches can be summarized as a systematic approach at one end of possibilities, and at the other end a range of ideas for thinking about the problem. The systematic approach stems from a single precept that a desired end state to a perceived problem or situation has practical ways of getting there.[8] This approach is suitable for structured problems or "hard systems thinking", and is what we most often see in engineering solutions to practical problems such as building construction and machinery design.[9] When the problem is less deterministic, perhaps a condition to be alleviated rather than solved, or more applicable to broad issues typical in the domain of strategy, a *methodology* is needed, not a method.

Methodology lies between the aforementioned systematic approach to problem solving and an idea or view of a system that requires greater understanding before it can be usefully tackled.[10] Whether it is called soft systems methodology, systemic operational design (developed by the Israelis in the mid 1990's), military operational design (as used by the US military), influence diagrams, or effects based operations—all involve a common approach.[11] That is to describe, or develop, a rich picture of the situation in which there appears to be a problem, and avoid any attempt to describe a preconceived notion of the problem.[12] It is *a way* of thinking

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[8] Checkland, *Systems Thinking, Systems Practice*, 138.
[9] Checkland, *Systems Thinking, Systems Practice*, 138–140.
[10] Checkland, *Systems Thinking, Systems Practice*, 162.
[11] Common approaches as described in; School of Advanced Military Studies, *Art of Design*, Version 2.0, n.d.
[12] Checkland, *Systems Thinking, Systems Practice*, 163; See also; Jamshid Gharajedaghi, *Systems Thinking Managing Chaos and Complexity: a Platform for Designing Business Architecture* (Burlington, MA: Morgan Kaufmann, 2011), 132–136.

about a problem before solving it, whereby the salient benefit is the journey of discovery, not the destination.

Strategy to address complexity has often suffered from the great promises of new technologies, revolutions in military affairs, and conflicting ideology. Although the human desire to model and predict is essential, the belief that we can drive to outcomes based on human intent in matters of complexity is hubris. US strategy has often rested on technology and the belief in American exceptionalism as fundamental dimensions to ensure success.[13] Applying similar deterministic thinking, technology and geography have been central to Australian strategy-making. In assessing whether a focus on a single, or a few dimensions of strategy, can maximize success Gray's central premise in *Modern Strategy* is a definitive no.[14] Certainly, he caveats, different dimensions may have greater or lesser influence at different times, but there is no historical evidence that any one of them can be overlooked.

This systems analysis offers a model for considering Australian strategy for the twenty-first century and the impact that spacepower (or lack thereof), might have. Without debating the pros and cons of what modern strategy *should* look like with a bias to preformed views nested in extant policy and doctrine, this chapter uses a dimensions of strategy framework to ask—what is the import of a spacepower perspective to inform a potential spacepower strategy for Australia.[15] A dimension of strategy approach identifies what is important with regard to an interest because it addresses importance in relation to other interests, and also relative to the interaction with the larger environment.

In the same way that an aircraft has been described as a flying platform underpinned by a myriad of other systems, the space system is

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13 Gray, *Modern Strategy*, 7.
14 Gray, *Modern Strategy*, 357.
15 Yarger, *Strategy and the National Security Professional Strategic Thinking and Strategy Formulation in the 21st Century*, 129–130.

far more than the satellites, launch systems, and ground controllers that encompass a customary understanding. To describe the space system, Figure 4 was developed in a mind map format, which encourages free thinking and the organic development of ideas.[16] It shows key nodes and their dependencies within a hierarchy; characteristics, influences and outputs of the system; and relative groupings indicating relationships within the system. Each element in Figure 4 is described in further detail below, from which a *so what* answer can be extracted.

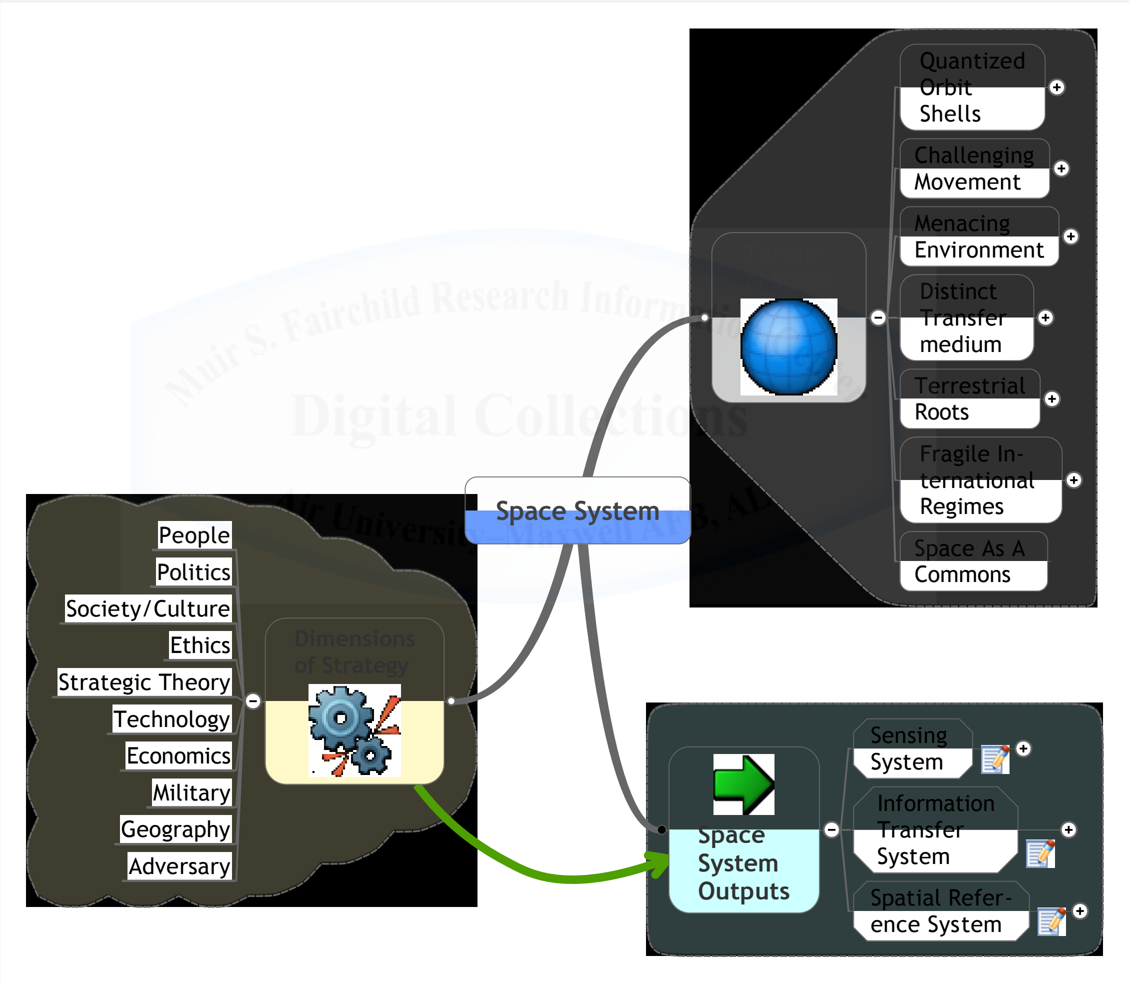

Figure 4: The Space System

Source: Author's original work.

[16] Tony Buzan, *Use Your Head* (London: BBC Books, 1989), 97; See also; School of Advanced Military Studies, *Art of Design*, 289.

The *Terroir* of Space

The very word space conjures an image that confuses a true understanding of the space system, or, in military parlance, the space domain. When most people think of space, they see it in negative relief, as anything *but* the Earth and its thin skin of atmosphere. Space is big, *really* big, so the potential view leaves an entire universe to fill the imagination.[17] Even within our solar system, there is a vast difference between many features: artificial satellites orbiting earth in low earth orbit (LEO), satellites in high earth orbit (HEO), debris fields, the orbit of the moon, and the orbit of the other planets. Such a confused view has not helped with the derivation of good strategy. In simple contrast, the surface of the ocean is the domain we associate with seapower, the surface of the land with landpower, and the atmosphere encompasses airpower—leaving little room for confusion.

I have deliberately used the French term *terroir* to encapsulate the special characteristics of space, as opposed to a constructivist approach that breaks down many of its constituent components. The terroir of space conveys certain characteristics and limitations that are exceptional and often distinctive from the terrestrial domains. These include: quantized orbit shells, a distinct transfer medium, terrestrial roots, fragile international regimes, a menacing environment, and challenging movement (see Figure 5).

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[17] Douglas Adams, *The Hitch Hiker's Guide to the Galaxy 1. The Hitch Hiker's Guide to the Galaxy.* (London [u.a.: Pan Books, 1979), 32.

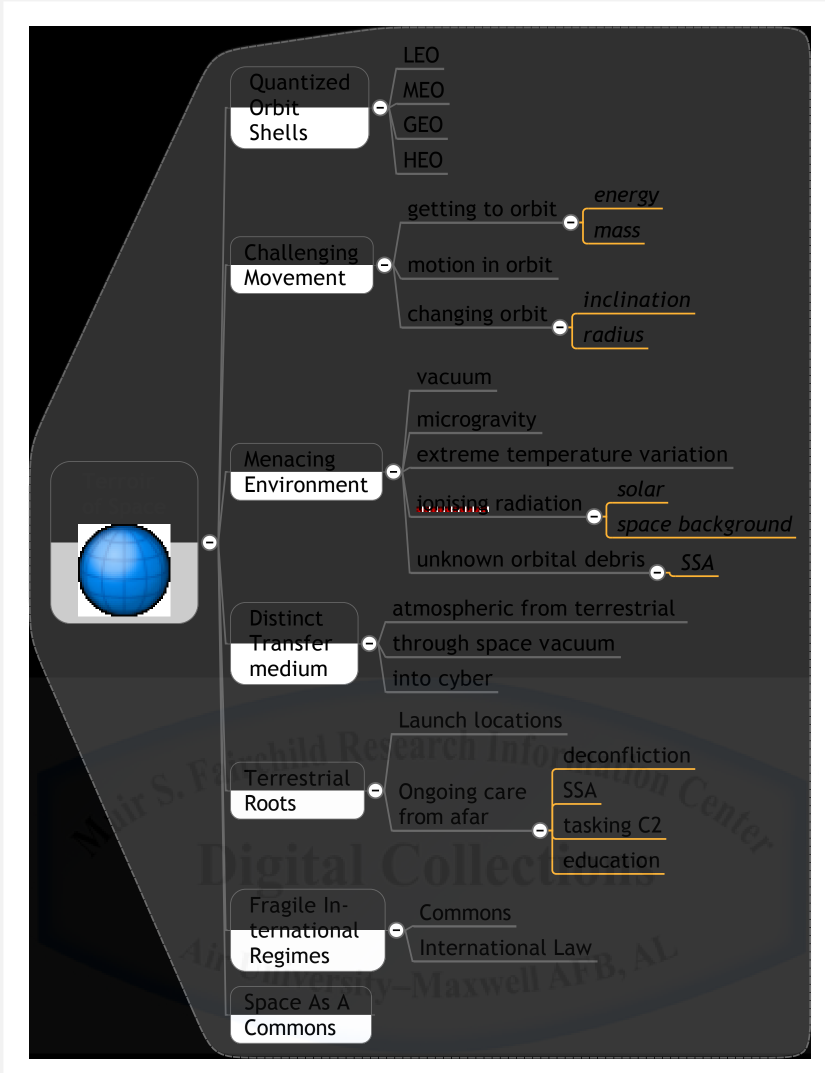

Figure 5: Terroir of Space

Source: Author's original work.

Quantized Orbit Shells

The following visualization is critically important in understanding the unique characteristics of space orbits and motion, so picture the following:

- The Earth, radius 6400 km is reduced to a globe whose radius is roughly 20 cm. On this globe, the 8 km high Himalayas appear as a 0.25 mm protrusion.

- The highest-flying commercial aircraft operate at an altitude of 13 km, breathing the rarefied air at 0.4 mm from the surface of the globe. Although rarefied, satellites are unable to operate this low due to the friction of the atmosphere bleeding their speed necessary to maintain orbit.
- Space begins (depending on whose definition you prefer) around 100 km. This equates to 3 mm above the surface of the globe. The actual delineation from the air domain to space is not as critical as terrestrial limits because there is a large expanse between the regions where neither air breathing aircraft can operate, nor satellites.
- The low orbiting International Space Station at 320 km altitude appears 1 cm above the globe.
- High satellites maintaining position around the equator in a geo-stationary orbit of 36,000 km sit 90 cm above the globe.
- The moon, at 31 earth diameters revolves a distant 620 cm above the globe.

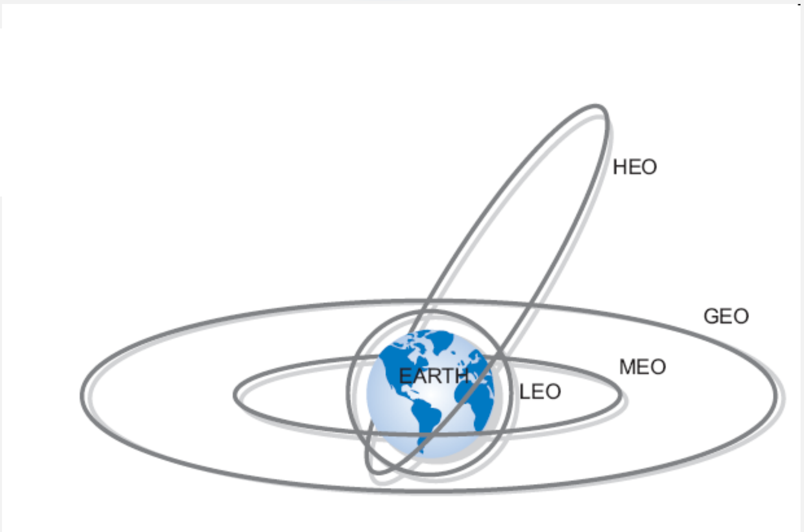

Figure 6: Satellite Orbits

Source: www.spacesecurity.org

The various orbits, as they trace a path form discrete shells, and are analogous to the energy shells that exist around each atom. According to quantum physics, the orbiting electrons around an atom's nucleus only exist in discrete quantized states, or discrete shells. Although satellites are able to move throughout various orbits in a smooth manner, they nonetheless find themselves, for practical reasons, congregated in these discrete shells.

LEO. Low Earth orbit (LEO), approximately 100-800 km is all about high speed, and small footprint.[18] Satellites in LEO tend to be optimized for high-resolution imagery (due to their proximity), or mobile communications that do not require a high-energy transmission from Earth. For the former, although satellites are completing an orbit every 90 minutes or so, the view is like looking through a fine straw out a car window—requiring that you need to know *what* to look at before getting there. For an example of the latter, the *Iridium* network uses 66 cross-linked satellites (six orbital planes of 11 satellites each) in LEO, 780 km above the Earth.[19] One satellite takes approximately eight minutes to pass from horizon to horizon, indicating how small the footprint of each satellite is.

MEO. Medium Earth orbit (MEO), approximately 800-30,000 km is the domain of communication and position satellites such as GPS, and allows for two to 14 orbits per day.[20] This region is especially harsh for electronics and solar arrays as it passes through the Van Allen radiation bands—swirls of high energy particles from the sun and space condensed by the Earth's magnetic field that degrade a satellite's life expectancy and are fatal to humans without heavy shielding. There is a relatively safe

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[18] Vallado and McClain, *Fundamentals of Astrodynamics and Applications*, 31.
[19] "Iridium-The Global Network: Satellite Constellation," September 1, 2010, 1, http://www.iridium.com/DownloadAttachment.aspx?attachmentID=1197.
[20] Vallado and McClain, *Fundamentals of Astrodynamics and Applications*, 31.

band; however, between the two large donut-shaped Van Allen belts in which the GPS navigation satellite system operates.[21]

GEO. Geosynchronous Earth orbit (GEO), approximately 35,800 km, is all about constant aspect to the Earth and large footprint. Satellites along the equatorial plane at GEO appear to hover over one point on the equator, allowing antennas on the ground to remain stationary and be built as large structures. Also, GEO satellites have a footprint, or can see approximately one third of the Earth from their vantage point, making it ideal for wide communications and low resolution Earth observation (such as weather satellites). Unlike LEO and MEO, the lesser orbits whose orbits can exist on a variety of different planes, positions for GEO exist on the equatorial plane, hence slots are limited and electronic interference from adjacent satellites is problematic.[22] GEO slots are a limited commodity, and valuable.

HEO. Highly elliptical orbits (HEO) are highly eccentric, passing as close as 250 km to Earth and receding to as far as 700,000 km in a 12-hour orbit. While at their furthest point, they appear to dwell overhead, offering the advantages of GEO, with the added advantage that they can be used off the equatorial plane. It benefits nations located at higher latitudes, such as the Russians who named the orbit *Molniya,* and are unable to make good use of GEO slots.[23]

Challenging Movement

Changing orbit in space involves a complex interplay of factors, characterized by an overwhelming drive for efficiency in order to maximize limited fuel supplies. Attention to efficiency dominates movement calculations due to the extremely large velocities of satellites,

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[21] Joan Johnson-Freese, *Space as a Strategic Asset* (New York: Columbia University Press, 2007), 35.
[22] Johnson-Freese, *Space as a Strategic Asset*, 35.
[23] Dolman, *Astropolitik*, 67.

in the order of tens of thousands of kilometers per hour. For example, an object needs a minimum velocity of 7.9 kilometers per second, a startling 28,440 kilometers per hour, just to match the earth's curvature and achieve a theoretical orbit. And because all orbits are in the shape of an ellipse with the Earth at one foci, velocity in orbit is not an independent variable—being dependent upon the size (or altitude) of the ellipse.

Velocity is also the major variable that dictates the force required to change momentum. The larger the velocity, the larger the force required to change speed or direction for a given unit of time. But this does not tell the whole story. The time taken to change velocity is also a factor, a shorter time requires greater force, and conversely longer time can be traded for lower force.[24] Unfortunately, the main propulsion sources used (rocket propulsion for the foreseeable future) tend to generate high thrust forces, and therefore act over shorter periods than a more efficient low thrust engine.[25] Although they are used sparingly in order to optimize efficiency, they must still generate significant force.

Propulsion in the terrestrial environment with land, sea, or air, vehicles requires the burning of fuel and oxygen—fuel is carried onboard and oxygen is extracted from the air. Spacecraft must carry both oxidizer and fuel, thus reducing the fuel load for a given capacity. Additionally, terrestrial vehicles can change direction by moving the fluid mass around them (for sea and air vehicles), or pushing against the solid earth. In space, there is nothing to push against so mass must be carried onboard to be ejected in order to impart a change in momentum. Remembering that anything carried into space must have attained a velocity of *at least* 28,440 kilometers per hour, the cost in fuel to deliver extra mass to space as a potential fuel source is extremely high compared to their terrestrial counterparts.

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[24] Jerry Jon Sellers et al., *Understanding Space: An Introduction to Astronautics* (New York: McGraw-Hill Companies, 2005), 114–115.
[25] Sellers et al., *Understanding Space*, 537–538.

Movement once in space also presents challenges. Although we now have the computing power to easily optimize specific flight profiles in space, one should not underestimate the extremely limiting constraints of fuel for energy and reaction, and the compromises this requires. Improved response, changes in inclination, different orbits—all generate the need for fuel, lots of fuel. And the penalty for getting that fuel to space in the first place is increased rocket size, more fuel again, and added cost and complexity. This is why the majority of satellites are carefully placed in an optimized orbit, never to change their orbits. Because they can move meaningfully over the Earth's surface, and continue to do so indefinitely due to an almost frictionless environment, this is accepted.

It also means that a satellites position and trajectory, once calculated, can be extrapolated to predict future positions—a phenomenon unique to space. Nonetheless, as alluded to earlier in the discussion of seapower and spacepower, without *regular* observations to fix and predict their next position, extrapolated positions become less accurate after each orbit. Ultimately, a satellite may quickly become lost through small maneuvers, thus realizing the Corbettian notion of an invisible force-in-being.

Satellite position and trajectory is obtained today using high-powered ground based radars to detect and track objects, complemented by telescopes to refine position calculations. Presently, only a handful of nations have a network of several sensors, and the US as the best provider of SSA is the only nation that has anything close to resembling global coverage.[26] Nonetheless, even the US SSA capability has gaps in coverage, exacerbated by the location and geographic distribution of its

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[26] Brian C. Weeden and T.S. Kelso, "Analysis of the Technical Feasibility of Building an International Civil Space Situational Awareness System," in *IAC-09.A6.5.2* (presented at the International Astronautical Congress, Daejeon, Republic of Korea, 2009), 1, http://swfound.org/media/1719/iac-09_bw.pdf.

tracking sites which were optimized for missile warning functions, not SSA.[27] And because the USAF makes public the orbital parameters of satellites and debris for any user, this primary source of data makes it both a strategic advantage for the US and its allies, as well as a global strategic vulnerability.

Menacing Environment

The space environment may appear empty and benign, but it is constantly awash in radiation, bombarded by high-speed particles, and beset by extreme forces.[28] The vacuum of space robs spacecraft of lubricants through outgassing, negates the use of conduction to exchange heat, binds metal surfaces in close contact, prevents the dissipation of static charges, and generally plays havoc with parts manufactured in a gaseous environment. The minimal microgravity environment ensures fluids can only flow when pumped, or through capillary action. Extreme temperature variations from just above absolute zero to hundreds of degrees Celsius are possible on alternate surfaces (facing the sun and away from sun). The Earth's magnetic field filters us from much of the radiation from the sun and space, but not so when in space. This radiation varies in strength over periods of hours, and contains enough energy to penetrate materials, disrupt electronic circuits, and black-out transmissions.

Radiation deserves special mention as it relates to resilience. The sun is a major source of space radiation, unpredictably spewing out high-energy particles that can degrade space services and affect linkages to the space system from the ground. Furthermore, energetic particles are constantly passing through spacecraft materials where they very

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[27] Weeden and Kelso, "Analysis of the Technical Feasibility of Building an International Civil Space Situational Awareness System," 2.
[28] Air University (U.S.). Air Command and Staff College and Air University (U.S.). Press, *Space Primer, AU-18* (Maxwell Air Force Base, Ala.: Air University Press, 2009), 115.

rarely have an impact—when they do, it has the potential to shut down critical computing systems in unpredictable ways. Developing resilience for spacecraft in the form of shielding or redundancy comes at a significant cost in launch weight and fuel expenditures. If such systems are critical for national security, then from a strategic perspective, perhaps the *state* should be demanding or paying for such resilience. This is a very different case from the commercial provider, who often mitigates their risk through insurance. This is fine for a company ledger, as a loss will be paid out, but does not suitably mitigate the state's risk, which must then bear the cost of lost capability to society.

The greatest risk to spacecraft is improbable but also highly consequential, does not diminish over time, and is exponentially increasing in its likelihood—debris. For the reasons described earlier, any orbital matter remains in orbit indefinitely, tracing the same path, at extremely high velocity. Space as a system is fragile because of this debris, where its ability to regenerate and clean-up is limited by the laws of orbital motion. Particles of paint, spent rocket motor parts, breakup fragments, and the minute detritus from humankind's endeavors in space represent a collision threat for spacecraft. Some particles in orbit *are* subject to atmospheric friction and ultimately re-enter Earth's atmosphere, where they are either incinerated or impact the ground. Nonetheless, the effect is marginal at anything but low altitude. For example, the time for a 1 cm radius sphere of mass 8.4 g to change its altitude by 100 km for circular orbits of 800 km and 1200 km takes an estimated 32 years and 455 years, respectively.[29]

The concern is not just that collisions are possible, but as first raised by Donald Kessler in 1978, that each collision will exponentially increase the risk of future collisions, even without further satellite

[29] Donald J Kessler and Burton G Cour-Palais, "Collision Frequency of Artificial Satellites: The Creation of a Debris Belt," *Journal Of Geophysical Research* 83, no. A6 (June 1, 1978): 2643.

launches to add to the debris catalog.[30] Since then, Kessler's conclusions have been superseded in their threat potential, better data and more accurate modeling shows that the threat is "collision cascading" such that the debris environment is already unstable, or above a critical threshold.[31] To place the threat in perspective, many view it as greater than the threat of anti-satellite (ASAT) weapons.[32] Figure 7 is a computer-generated image of tracked debris in LEO Earth orbit, visually demonstrating the ongoing debris threat. Although this is, of course, intentionally misrepresented, as each "particle" of debris (none larger than a satellite and most about the size of a coke can), is depicted here as larger than metropolitan Sydney—they are nonetheless orbiting continuously at high speed. As another representation, Figure 8 shows the number of objects *tracked* in space by the US DOD over time, and does not include the estimated millions of additional debris objects too small to track via terrestrial sensors.[33] Of the two figures, the latter is the most indicative of the trend feared by Kessler—an apparently exponential growth in the threat.

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[30] Kessler and Cour-Palais, "Collision Frequency of Artificial Satellites: The Creation of a Debris Belt," 2644–2645.
[31] Donald J Kessler, "The Kessler Syndrome," March 8, 2009, 4,5, http://webpages.charter.net/dkessler/files/KesSym.html.
[32] John Johnson cited in; Joseph S Imburgia, "Space Debris and Its Threat to National Security: A Proposal for a Binding International Agreement to Clean Up the Junk," *Vanderbilt Journal of Transnational Law* 44, no. 3 (May 2011): 598.
[33] Jaramillo, *Space Security 2011*, 28–29.

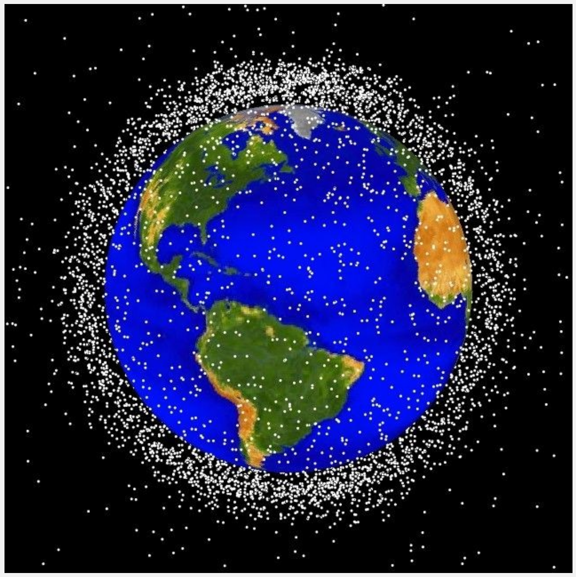

Figure 7: LEO Orbital Debris Graphic

Source: NASA Orbital Debris Program Office
http://www.orbitaldebris.jsc.nasa.gov./photogallery/beehives.html#leo

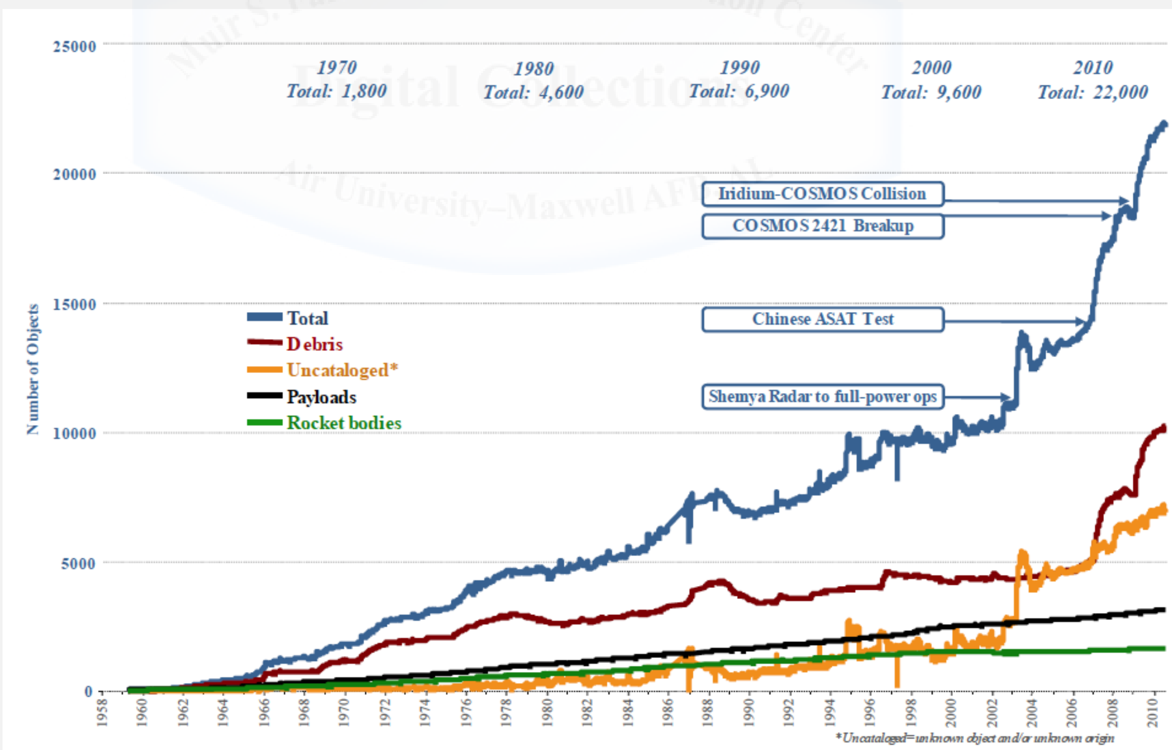

Figure 8: Space Orbital Catalogue

Source: DoD, "National Security Space Strategy -Unclassified Summary", January 2011, http://www.dni.gov/reports/2011_nationalsecurityspacestrategy.pdf.

Several proposed mitigation strategies to the dilemmas above are typical in their approach that treats the problem as structured, but fail to recognize the system issues of exponential growth and the futility of conventional strategies (such as shielding). A hard power approach espoused, or rather *concluded,* by the *Astropolitik* model is the seizure of low earth orbit by the US.[34] Though unable to dominate space Australia could, *inter alia*, support *Astropolitik's* idea of a national space coordination agency. Conversely, approaches from a liberalist perspective decrying a unilateral *Astropolitik* approach as practically guaranteeing conflict (and hence creating debris), recommends multilateralism, hence also offering the potential for Australian involvement.[35]

A different, systems approach is to consider the problem as a condition to be alleviated, rather than solved.[36] While emphasis is being placed on improved space situational awareness (SSA) and an expectation of operating in a degraded environment, practical recommendations are lacking.[37] The possibility that LEO might become unusable in future needs to be addressed holistically. For Australia, an obvious effort to support SSA should continue as directed in the 2009 Defence White Paper, but other approaches should encompass a resilience focus.[38]

Distinct Transfer Medium

The only *practical* means to transfer information to and from space is through the use of the "wireless" electromagnetic spectrum—via radio communications. Apart from a small excursion during the cold war to drop film intelligence packages from LEO to be picked up by ships or

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[34] Dolman, *Astropolitik*, 157.
[35] Mike Moore, *Twilight War: The Folly of U.S. Space Dominance* (Oakland, Calif.: Independent Institute, 2008), xvi.
[36] Checkland, *Systems Thinking, Systems Practice*, 155.
[37] DOD, "National Security Space Strategy -Unclassified Summary," 4–5.
[38] Australia. Dept. of Defence., *Defending Australia in the Asia Pacific Century*, 85.

scooped out of the air by waiting aircraft, information between Earth and space passes as a radio wave through the atmosphere and space environment.[39] These paths can be jammed, or a charged atmosphere can debilitate signals to deny useful value from space. Because there are no redundant or backup transmission paths, it is a singular vulnerability that adds another factor diminishing resilience.

Terrestrial Roots

Once in orbit, spacecraft are largely on their own, never to be repaired or refueled like their terrestrial counterparts. Nonetheless, they do still require some human intervention to maintain their orbit under the influence of minor perturbations, and to be commanded for missions and system management. Therefore, a terrestrial foundation must be maintained, as well as the links between ground and space. Depending on the coverage and temporal access required, ground stations may be scattered around the globe for any one satellite or constellation. As an example, Australia has long provided satellite ground station basing in support of the US, both at Nurrungar, near Woomera, and at Pine Gap, near Alice Springs.[40] This is one way Australia contributes to a space partnership without directly launching and maintaining its own constellation.

Fragile International Regimes

The treaties, customs and resolutions pertaining to space activities were developed in an environment of Cold War tensions that no longer apply and do not provide the means to address issues relating to defense of critical and complex systems. Following the launch of *Sputnik,* in order to legitimize overflight of its reconnaissance satellites, the US sought to

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[39] Neil Sheehan, *A Fiery Peace in a Cold War: Bernard Schriever and the Ultimate Weapon* (New York: Vintage Books, 2009), 434–436; Johnson-Freese, *Space as a Strategic Asset*, 37.
[40] Australia. Dept. of Defence., *Defending Australia in the Asia Pacific Century*, 94–95.

establish a legal right to do so.[41] In turn, this led to the 1967 Outer Space Treaty, the *Magna Carta* of space, that upholds the principle that international law applies in space, and specifically bars concepts of sovereignty and ownership.[42] From a national security perspective, the intentionally imprecise nature of agreements that suited Cold War politics are now too imprecise for the extant objective of order and unimpeded access to space. Additionally, international law, unlike national law, is very difficult to enforce and argue.

Key principles under the Outer Space Treaty include article I—outer space shall be free for use by all states; and article IV—states parties to the treaty shall not place in orbit any objects carrying nuclear weapons or other kinds of weapons of mass destruction.[43] Many authors interpreting this, possibly applying terrestrial notions of force to the space domain, focus on the weaponization of space—should or should it not be weaponized, what is a weapon, and so on. From the perspective of an understanding of the system, it can be seen that conventional weapons are a misnomer, and also of limited use in space. Any object in orbit already has far greater kinetic energy than the stored energy available in an equivalent mass of high explosive, and therefore it can be inferred that any orbiting object that can be maneuvered *is a weapon.* Furthermore, the difficulties of getting into space increase the likelihood of weapons originating from Earth. These might take the form of dazzling lasers to blind optical sensing elements, or jamming radiation to prevent

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[41] McDougall, *The Heavens and the Earth*, 109.
[42] Michael J Sheehan, *The International Politics of Space* (London; New York: Routledge, 2007), 70. The Outer Space Treaty is the common name given to the "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies".
[43] United Nations. Office for Outer Space Affairs and United Nations. General Assembly, *United Nations Treaties and Principles on Outer Space Text of Treaties and Principles Governing the Activities of States in the Exploration and Use of Outer Space, Adopted by the United Nations General Assembly.* (New York: United Nations, 2002), 4, http://www.unoosa.org/pdf/publications/STSPACE11E.pdf.

information being received on, or from earth. Because the classification of weapons in a space context is difficult to define, it raises the specter of activities being conducted by actors in the mistaken belief they are not breaking international law.[44]

Space as a Commons

Space has been designated a commons, it borders the territorial airspace of every nation (overhead), and is recognized as a domain free for use by all without restriction. Space is a commons through human intention, but also stemming from its terroir. Orbitology dictates that satellites trace out elliptical shells that often share a common intersection between other shells, and this requires collaboration amongst the space-faring actors if the system is to survive.[45]

The designation was appropriately politically correct during the early evolutions of space exploration, but as Dolman astutely points out, "common ownership and fraternal exploitation do not entirely mitigate the competitive nature of a society."[46] On Earth, in a story all too familiar to ocean fisheries today, the tragedy of an unregulated commons arises when the regenerative capacity of the commons is exceeded by resource depletion, with a resulting loss to all.[47] This can only be avoided through the dubious notion of benevolent self-regulation, establishment of a political/legal constraint, or a parsing out of the resource such that the commons is now in private holdings—though this too does not guarantee long-term viability.

The commons analogy as it applies to space is disputed by some, though the concept of a commons is too often misconstrued as being the

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[44] Duncan Blake and Joseph Imburgia, "Bloodless Weapons'? The Need to Conduct Legal Reviews of Certain Capabilities and the Implications of Defining Them as 'Weapons," *The Air Force Law Review* 66 (2010): 172, 184.
[45] Moltz, *The Politics of Space Security*, 11.
[46] Dolman, *Astropolitik*, 96.
[47] Meadows, Randers, and Meadows, *The Limits to Growth*, 229–233.

same thing as the concept of the high seas, whereby *commons* becomes another descriptor for *maritime*.[48] What is missed is that overuse of the commons destroys its utility for all. Considering debris, an approach to the commons is to convey the specter of cascading debris in the same light as nuclear war—that the lingering after-effects and damage to all parties provides no advantage to the first to defect (using the prisoner's dilemma analogy).[49]

Dimensions of Strategy

The strategic environment when framed as a system reveals the relationships between elements, their interdependencies, and influence on the whole.[50] What is not seen in the final product is the multitude of considerations that influenced development of the system overview that ultimately serves as a filter to bring key strategic factors to the fore. The following analysis, modeled partly on a *dimension of strategy* approach suggested by Gray and Yarger, considers each dimension as it applies to the space system, with an Australian strategic bias in mind (Figure 9).[51]

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[48] Krepon, et al, "Preserving Freedom of Action in Space: Realizing the Potential and Limits of U.S. Spacepower", in; Lutes and Hays, *Toward a Theory of Spacepower*, 123.
[49] See Robert M Axelrod, *The Evolution of Cooperation* (New York: Basic Books, 2006), 9.
[50] Yarger, *Strategy and the National Security Professional Strategic Thinking and Strategy Formulation in the 21st Century*, 124–129.
[51] Gray, *Modern Strategy*, 23–44; Yarger, *Strategy and the National Security Professional Strategic Thinking and Strategy Formulation in the 21st Century*, 129.

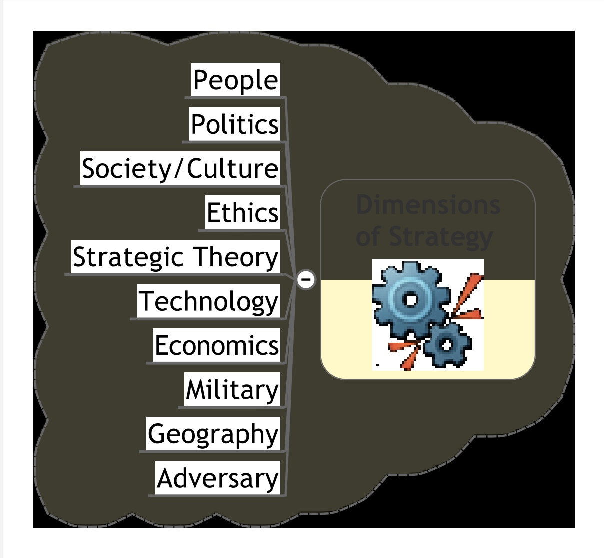

Figure 9: Dimensions of Strategy

Source: Authors original work.

Politics

When the aims of the state are derived without a holistic understanding of the state as an entity, tragedy usually follows. Japan's entry into World War II was a strategy to ensure access to resources for state survival, and was predicated on the hopeful assumption that the US would not retaliate and rested on high expectations (hope and chance), but its strategy was erratic and lacked the integration of all forms of power.[52] What characteristics might a nation have that can weave inputs from the government, the military, and the people to form a national vision and achieve consensus. Any nation having such characteristics is one that is likely to be good at strategy

A government that is responsible for the well-being of the state is going to be better at strategy than one that focuses on personal gain at the expense of the state. Although some dictatorships understand that their power derives from the state and are savvy in executing strategies

[52] D. James, "American and Japanese Strategies in the Pacific War"; cited in Paret, Craig, and Gilbert, *Makers of Modern Strategy*, 703.

that ensure their survival, they run an increased risk by default. That is, a state's overall power tends to erode in a reductionist strategy that is not aligned to the purposes of (holistic) state well-being. A government that rewards performance and recruits the best possible minds is more likely to arise from a functioning democracy, or a very smart *benign* dictatorship. Egomaniacs do not qualify.

Australia is well structured to avoid the problems raised above, ranked as it is, the world's sixth most democratic nation according to the Economist Intelligence Unit's Democracy index.[53] A relevant factor considered in the calculation values a transparent and efficient government, free of undue influence from the military.[54] The Australian military is a professional volunteer force, subject to the direction of the elected party. For spacepower to gain traction as an essential element of Australian national security strategy, it needs to be addressed both politically and militarily, from a whole of government and joint military perspective.

People

People matter; for no matter how well constructed a strategic theory, real people must execute and do strategy.[55] Australia's large geographic size is a counterpoint; however, to its relatively small population. Although only slightly smaller than the contiguous 48 states of the United States, its population of 22 million (ranked fiftieth in the world) is only seven per-cent of the US population of just under 314

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[53] "Democracy Index 2011, Democracy Under Stress, A Report from the Economist Intelligence Unit," December 2011, 3, http://www.sida.se/Global/About%20Sida/S%C3%A5%20arbetar%20vi/EIU_Democracy_Index_Dec2011.pdf.
[54] "Democracy Index 2011, Democracy Under Stress, A Report from the Economist Intelligence Unit," 34.
[55] Gray, *Modern Strategy*, 26.

million (ranked third in the world).[56] Although a wealthy country, Australia's population is a significant limitation that diminishes its strategic weight and reach.

Spacepower is proportionally less dependent on people than other forms of military power, with the possible exception of cyberpower. The products from spacepower—intelligence, data, information—all require people to process and use that information, with the advantage they can be electronically interfaced to the information, with a very small logistical overhead. This contrasts with land forces that must physically exist in their theatre of concern. Consider the US Army, whose tooth-to-tail ratio now lies somewhere between10 to 20 per-cent (combat forces in proportion to support).[57] Spacepower; however, requires significant up front investment, but once in operation, its useful life and payoff is measured in years. The ongoing benefits to the military and society are achieved through a tradeoff, where the investment in technology reduces the human cost. This makes sense for Australia.

Society/Culture

Australia's early involvement in space arose circuitously via an international collaborative partnership in response to the crisis presented by Sputnik. Australia committed use of its vast, sparsely populated interior as a launch range from the township of Woomera, and in the dying days of the project, Australia developed satellite technology for the payload component on a donated US Redstone rocket. Its successful launch to orbit made Australia the fourth country to launch its own satellite into space, though clearly this did not go so far as to

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[56] "CIA - The World Factbook," n.d., https://www.cia.gov/library/publications/the-world-factbook/geos/us.html.

[57] John J McGrath, *The Other End of the Spear: The Tooth-to-Tail Ratio (T3R) in Modern Military Operations*, 2007, 65–67.

make Australia a spacefaring nation.[58] From the heyday of space related activity at Woomera in the 60's, little has occurred since. For airpower, Australia formed the world's fourth independent air force, and the fascination of air travel has not abated since. Perhaps Australia's geographic displacement from the rest of the world had a particularly formative influence during the early years of post-colonial independence. Space activity, it would appear, does not infuse Australian strategic culture to the same extent.

This may be too simplistic an explanation. An alternative view is that the issue is too complex, the cost-benefit relationship too interwoven with ill-defined variables that the strategist is (unknowingly) unable to address the problem.[59] Consider that Australia's strategic culture has been well disposed to the use of conventional force in the interests of the state through a history of external engagements. Australian land, air, and seapower have been soundly employed in wars across the globe, either as the contribution of a dominion of Great Britain at the turn of the twentieth century (the Boer War); or as an independent nation during: World War I, World War II, Korea, Malaya, Vietnam, the first Gulf War, the Iraq War and the Afghan War. The historical legacy has translated to conventional military force that can operate across the full spectrum of conflict; from supporting peacetime national interests, through to conventional state-on-state conflict.

Australian national security space policy contrasts peculiarly with the "can't do without" debate that characterizes much of Australian strategic discussion. The traditional and familiar cultural response to Australian national security needs updating to account for complexity—for spacepower.

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[58] Brett Biddington, Roy Sach, and Kokoda Foundation., *Australia's Place in Space: Toward a National Space Policy* (Kingston, A.C.T.: Kokoda Foundation, 2010), 13.
[59] Langford, "An Existential Approach to Risk Perception," 25.

Ethics

Ethics, according to Gray, can be vitally important to strategic importance but are often formally neglected.[60] E.H. Carr adds that neither the utopian view that politics are a function of ethics, nor the realist view that ethics are a function of politics are correct. Rather, sound political thought must be based on both.[61] The Australian view is pragmatic. It officially supports conformance to international obligations when considering the use of force and states that force is permitted only in certain circumstances—where authorized by the United Nations Security Council or in self-defense.[62] For a spacepower strategy, this has significant implications for Australia.

In his book *Astropolitik,* Dolman applies a theoretically narrow realist geopolitical construct to space and concludes that an *Astropolitik* strategy for the US would necessitate a withdrawal from current space regimes and the implementation of US military domination of LEO.[63] Gray similarly suggests that although the defense is stronger in MEO and HEO, an offensive posture is suited in LEO.[64] However, an offensive posture in space is unlikely to be adopted by Australia. Therefore, a more nuanced approach needs to be considered; perhaps deterrence might satisfy the ethical policies whilst supporting a spacepower concept.

Without a crucible of conflict to draw a theory of space deterrence from, an alternative source of guidance comes from scenario development, which is a tool to greater understanding and prediction.[65] In military terms, this is enacted through war games, and the Schriever Wargame (SW) series run by US Air Force Space Command provides an

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[60] Gray, *Modern Strategy*.
[61] Carr, *The Twenty Years' Crisis, 1919-1939*, 87.
[62] Australia. Dept. of Defence., *Defending Australia in the Asia Pacific Century*, 30.
[63] Dolman, *Astropolitik*, 1,3,156–157.
[64] Gray, *Modern Strategy*, 257.
[65] Peter Schwartz, *The Art of the Long View: Paths to Strategic Insight for Yourself and Your Company* (New York: Currency Doubleday, 1996), xiii.

outstanding example of testing space and cyber power in future conflict. In the SW 2010 scenario, conflict in space and cyberspace quickly escalated, drawing in other domains towards global conflict. The conclusion reached was that Cold War deterrence theories, delays resulting from interagency consensus seeking, and a lack of defined trip wires; were ill-suited for space and cyberspace in the "extraordinarily complex" world of the future.[66]

Military planners traditionally address an enemy's capabilities, not their intentions. "But deterrence is about intentions - not just *estimating* enemy intentions but *influencing* them" says Thomas Schelling, the master of deterrence theory.[67] To influence intentions and improve deterrence for space security, the US has already declared it will establish global norms of behavior, form space coalitions, and respond in self-defense to attacks in space. Australia already has an enduring partnership with the US that could be strengthened for space, in the same way that a cyber-attack on either country is now a trigger for the ANZUS treaty.[68] And, as Australia has some influence on the world stage that belies its size, it need do no more than publicly state its intention in this regard. However, in order to effect such policy, the importance of space to national security needs to be formally recognized—a view not easily accepted without an understanding of space as a complex system.

Strategic Theory

Somewhat surprisingly for a modern well-resourced nation, and a decade into the twenty-first century, a formal national security policy for

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[66] Robert S. Dudney, "Hard Lessons at the Schriever Wargame," *Airforce Magazine*, February 2011, 58, http://www.airforce-magazine.com/MagazineArchive/Documents/2011/February%202011/0211wargame.pdf.
[67] Thomas C Schelling, *Arms and Influence* (New Haven, Conn.; London: Yale University Press, 2008), 35.
[68] "Cooperation on Cyber – a New Dimension of the US Alliance, Media Release, Australian Minister for Foreign Affairs," September 15, 2011, http://www.foreignminister.gov.au/releases/2011/kr_mr_110916.html.

Australia does not exist. This is not to suggest that little attention has been given to national security. If funding is one clear indication of where a nation considers its interests lie, then boosted funding to: defense, intelligence services (both domestic and international), and overseas foreign aid following the *First National Security Statement To The Australian Parliament* made in December of 2008 provides an indication.[69] The statement was ground-breaking for Australia, and partly addressed concerns made by policy analysts during the preceding decade who advocated the need for an Australian national security strategy in response to an increasingly complex world.[70]

A *coherent* national security strategy involves much more than the capabilities and functions of the defense force. Increasingly, a whole of government perspective is necessary to adequately address the increasing number of threats that impinge upon national security. Force structuring for space, for example, is difficult—the investment is high, and capabilities have strategic as well as tactical value and can therefore be shared. A rational approach follows one of two methods. Either planning is threat specific, indicative of a "structured problem" in systems jargon; or the threat is ambiguous, which makes it complex and more suited to a complex systems approach.[71] Australia lacks a direct credible threat, and therefore the latter scenario dominates.

Officially though, the core of Australian security strategy that is used for planning is the "defence of Australia against direct armed attack … irrespective of the perceived intentions of others."[72] Other strategic interests form a basis for defense planning, and although lacking

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[69] Carl Ungerer, *The Case for an Australian National Security Strategy* (Australian Strategic Policy Institute, July 28, 2011), 1–2.
[70] See; Michael Evans, "Towards an Australian National Security Strategy: A Conceptual Analysis," *Security Challenges* 3, no. 4 (November 2007): 113–130.
[71] Checkland, *Systems Thinking, Systems Practice*, 138–140.
[72] Australia. Dept. of Defence., *Defending Australia in the Asia Pacific Century*, 12.

guidance from a national security strategy, and geopolitical in outlook, are promulgated as follows:

- A secure Australia,
- A secure immediate neighborhood,
- Strategic stability in the Asia-Pacific region, and
- A stable, rules-based global security order.[73]

For a country like Australia, a medium power with few of its own space capabilities, two dilemmas arise. The first dilemma lies between a neo-liberalist approach that is potentially cheaper militarily, balanced against a neo-realist national security strategy that declares that war among states is not dead.[74] Perhaps President Eisenhower got it right in the weeks following *Sputnik's* launch—that in matters of space, speaking of idealism and acting with realism is warranted.[75] The second dilemma is a notion of self-reliance to deter and defeat an armed attack on Australia, while acknowledging a degree of external-reliance on its allies in capabilities such as space systems.[76] A literal interpretation of self-reliance appears to conflict with Australia's growing military reliance upon borrowed space systems that provide capabilities across the full spectrum of war—so how might this be reconciled?

Peter Schwartz, one of the world's leading futurists argues in *The Art of the Long View* that people in resilient organizations "continually hold strategic conversations about the future."[77] He then describes strategic conversation; as something remarkably similar to systems thinking and design as advocated in this thesis—a framing of the situation to illuminate planning efforts, where the journey is as

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73 Australia. Dept. of Defence., *Defending Australia in the Asia Pacific Century*, 41–43.
74 Sheehan, *The International Politics of Space*, 73; Australia. Dept. of Defence., *Defending Australia in the Asia Pacific Century*, 22.
75 McDougall, *The Heavens and the Earth*, 178.
76 Australia. Dept. of Defence., *Defending Australia in the Asia Pacific Century*, 48–49.
77 Schwartz, *The Art of the Long View*, 221.

important as the output. As important as a formal national security strategy might be, of greater importance is informal discussion within a formal planning framework that is never-ending. Discussions with Australia's principal ally, the US, should frame the space system as a larger, complex problem to be shared, or rather, contributed to by a larger pool of actors. What might then result are collaborative and joint ventures where the whole is greater than the sum of the parts.

Technology

Explanatory theories abound detailing the techniques, steps and conditions required for successful technological innovation. At one extreme, technological determinists such as Ray Kurzweil, characterizing the growth of computation, concludes nothing can stop the development of a technology that is underpinned by an exponential rate of growth.[78] Conversely, social constructivists argue that technology is but one element, and echoing a systems view, they say other factors of importance include social, economic, scientific, and political dimensions.[79] Technological innovation requires a plan, but the theory of complex systems suggests that few understand the requirements for successful innovation.

Three things influence technological innovation in a military setting. First, the external environment (to the military) has a significant effect on innovation, and this environment must be optimized for innovation. Second, the internal cultural and organizational environment of the military can either stymie or support innovation, and knowing this leads to different proactive strategies for innovation. Finally, small groups and individuals are essential to drive major innovation through,

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[78] Kurzweil, *The Age of Spiritual Machines When Computers Exceed Human Intelligence*, 35.
[79] Wiebe E Bijker et al., *The Social Construction of Technological Systems* (Cambridge, Mass.: MIT Press, 1987), 3.

therefore, the selection and creation of such groups is another proactive development to drive innovation.

According to Barry Posen, the internal environment of the military when left to its own devices tends towards an offensive doctrine, a disintegrated approach between the services, and a stagnant degree of innovation.[80] Stephen Peter Rosen argues the problem of military innovation is one of bureaucratic innovation.[81] Both authors are fundamentally basing their conclusion on an assessment of organizational theory, not technology *per se*. Therefore, an understanding of organizational culture (in theory) is necessary for driving innovation. Within the Australian Defence Organisation (ADO), strong support for spacepower and a supportive structure ensures the appropriate level of attention is being focused. These include scientific developments facilitated by the Defence Science and Technology Organisation (DSTO), doctrine development, space education, and broad consideration of spacepower in capability development.[82]

Individuals and small groups are an essential element to the success, or otherwise, of military innovation. Irving Janis in *Groupthink* argues that a fourth conceptual model should be added to Allison and Zelikow's *Essence of Decision* three level model to specifically consider the behavior of the small group decision maker.[83] The inclusion of a small groups model fills an analytical hole for many historical examples

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[80] Barry Posen, *The Sources of Military Doctrine : France, Britain, and Germany Between the World Wars* (Ithaca, N.Y.: Cornell University Press, 1986).
[81] Stephen Peter Rosen, *Winning the Next War : Innovation and the Modern Military* (Ithaca: Cornell University Press, 1991), 2.
[82] See for example; Commonwealth of Australia, "Operations Series, ADDP 3.18, Operational Employment of Space," June 8, 2010, http://www.defence.gov.au/jwdtc/Documents/DoctrineLibrary/ADDP3.18-OperationalEmploymentofSpace.pdf.
[83] Irving L Janis, *Groupthink: Psychological Studies of Policy Decisions and Fiascoes* (Boston: Houghton Mifflin, 1982), 4; Graham T Allison and Philip Zelikow, *Essence of Decision: Explaining the Cuban Missile Crisis* (New York: Longman, 1999).

demonstrating the critical impact of these groups. In Australia, the Defence Space Coordinating Office (DSCO) formed in 2006, and the governments Space Policy Unit (SPU) formed in 2009, are just two examples of small groups now playing a key role in developing space related strategy.[84] The role of DSCO fits well within a systems model, as its role is a Defence point of contact to coordinate discussion through engagement rather than dictate direction—facilitating the journey rather than dictating the destination.[85] The SPU, in a similar holistic manner, has established approximately $40m in funding to support a broad level of space related initiatives, from education at all levels, to specific space technologies.[86]

Australia now sits on the cusp of making a meaningful and unique contribution to space security through SSA. In November 2010, Australia and the US signed a "Space Situational Awareness Partnership Statement of Principles" to collaborate on SSA, manifested initially through the establishment of a joint space tracking facility in Western Australia.[87] As discussed earlier, one weakness of the US SSA capability is a lack of coverage in the Southern Hemisphere.[88] As part of a Coalition Space Operations Center, or CSpOC, an SSA capability from Australia could fill a gap and improve temporal fidelity for the network. Additionally, niche technologies such as the Automated Laser Tracking of

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[84] "Department of Industry, Innovation, Science, Research and Tertiary Education - Space," n.d., http://www.innovation.gov.au/Industry/Space/Pages/default.aspx.
[85] Nick Merret, "Lost In Space: New Directions for the Heavens from National Security Statement," *Australian Defence Business Review*, January 2009, 43–44.
[86] See; "Australian Space Research Program," n.d., http://www.space.gov.au/AustralianSpaceResearchProgram/Pages/default.aspx.
[87] "AUSMIN 2010 Joint Communiqué, 8 November 2010, Australian Government Minister for Foreign Affairs," November 8, 2010, http://www.foreignminister.gov.au/releases/2010/kr_mr_101108.html.
[88] Weeden and Kelso, "Analysis of the Technical Feasibility of Building an International Civil Space Situational Awareness System," 2.

Space Debris project are being supported, that promise to add to SSA capability in a meaningful way.[89]

Finally, SSA assists responsible behavior. As demonstrated in the discussion of space as a menacing environment, it may be difficult to ascribe the reason for a system disruption, and if a stealthy sabotage or attack can be conducted with impunity, the likelihood of unlawful behavior increases. For deterrence to work, the protagonist must also be known, and improvements to SSA assist to reduce uncertainty.[90] Concluding, an Australian contribution to SSA has three benefits: it supports Australian niche technologies that are world class, it meaningfully contributes to Australia's strongest ally, and it contributes to improved space security for the benefit of all users.

Economics

Although only one indicator of economic potential (though it is popularly used), Australia's Gross Domestic Product (GDP) is ranked nineteenth in the world, and its GDP per capita is also nineteenth.[91] In terms of national security significance, the gross value, or GDP is of greater significance. A useful contrast of Australia's population and GDP compared to its neighbors is shown in Figures 10 and 11 using density equalized maps, where areas are equalized to the variable being mapped.[92] Figure 10 is a population estimate for the year 2050. Note the size of Australia in relation to its Asia-Pacific neighbors. The second map,

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[89] Neil Gordon, An Update on SSA in Australia; "Advanced Maui Optical and Space Surveillance Technologies Conference 2011: AMOS 2011, 13-16 September 2011, Maui, Hawaii, USA." (New York: Curran, 2011), 544–553.

[90] Robert Jervis, "Deterrence, Rogue States, and the U.S. Policy", in T. V Paul, Patrick M Morgan, and James J Wirtz, *Complex Deterrence Strategy in the Global Age* (Chicago: University of Chicago Press, 2009), 134.

[91] "CIA - The World Factbook," n.d., https://www.cia.gov/library/publications/the-world-factbook/rankorder/2004rank.html.

[92] "Worldmapper: The World as You've Never Seen It Before," n.d., http://www.worldmapper.org/about.html.

Figure 11, shows equalized wealth as GDP in US dollars for 2015. GDP in Australia's immediate neighborhood looks similar; nevertheless, it is dwarfed by China, Japan, and India.

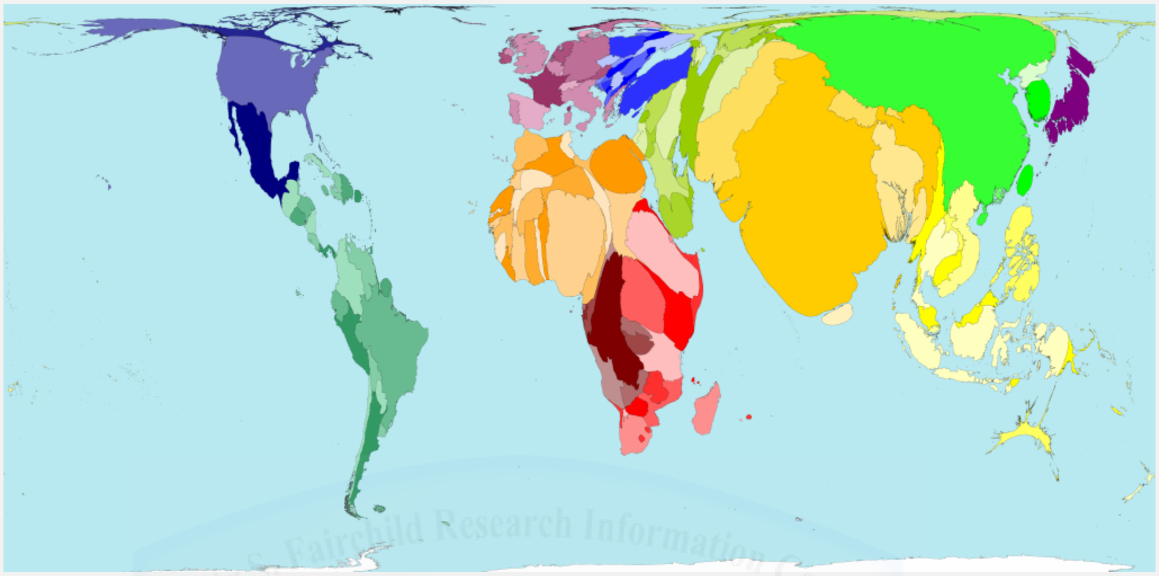

Figure 10: Equalized Population Projection 2050

Source: www.worldmapper.org

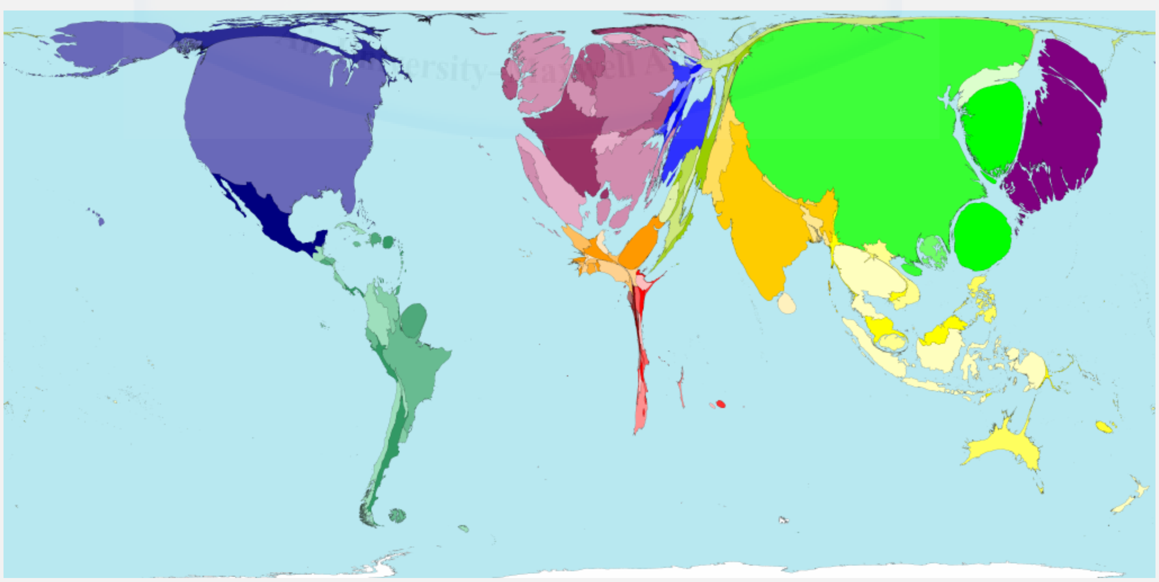

Figure 11: Equalized GDP Projection 2015

Source: www.worldmapper.org

Nations with space agencies in Australia's neighborhood include Japan, Malaysia, Indonesia, Vietnam, and India. Australia, as a relatively wealthy country, might do more to develop relationships with these agencies, with the goal of developing greater resilience. Rather than being seen as a dilution of the relationship between Australia and the US, Australia's strong position in a regional space partnership could add value to its primary ally. The investment Australia has made in space related activities is not matched against the significance space has for its modern society, nor is it matched by its neighbors.

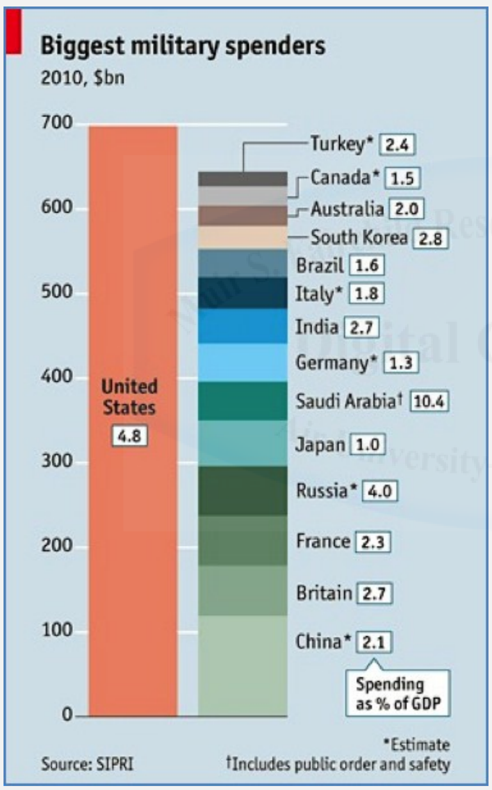

Figure 12: Military Spending as % of GDP

Source: The Economist, June 8 2011

The entry cost to operate in space is prohibitive. Although Australia made a brief foray into space on November 29, 1967, becoming the fourth nation in the world to launch its own satellite (albeit on a US Redstone rocket), it failed dismally to capitalize on its lead.[93] Consequently, the Australian situation differs significantly from that of the US, which has prime aerospace manufacturers and significant government investment to consider. It would now be prohibitively expensive for Australia to build from scratch a space launch industry without partners, and private venture capital is even more unlikely to tackle this challenge, as it is not only highly risky but also capital

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[93] WRESAT - Weapons Research Establishment Satellite on an American Redstone rocket; Daphne Burleson, *Space Programs Outside the United States: All Exploration and Research Efforts, Country by Country* (Jefferson, N.C.: McFarland, 2005), 10.

intensive.[94]

This is not to suggest that there is little public support or meager defense funding. Figure 12 shows Australia's defense spending at 2% of GDP, ranked thirteenth in the world. For a country globally ranked nineteenth in terms of GDP, it suggests that Australians have a realist approach to security that recognizes the value of force as an instrument of security.[95] Nonetheless, strategy is a means of rationally apportioning resources between competing interests; "unlimited resources would render strategy unnecessary".[96]

In a cost sharing initiative between the US and Australia, the Australian Department of Defence is funding the equivalent value of one Wideband Global System (WGS) satellite to complement the WGS constellation.[97] The US has effectively traded bandwidth access for improved coverage and capability of the system—an astute move that now appears to be drawing in other partners such as New Zealand and Canada.[98] The benefits of such collaboration with Australia's major ally are clear, and represent a more integrated approach to developing space capabilities. Furthermore, Australia is moving to increase direct capabilities through a hosted payload on a US Iridium satellite, and acquisition of a remote sensing satellite.[99] All of the above initiatives are

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[94] Lewis D Solomon, *The Privatization of Space Exploration: Business, Technology, Law and Policy* (New Brunswick, N.J.: Transaction Publishers, 2008), 72.
[95] Andrew Shearer, *The US Alliance in Australia's New Era of Strategic Uncertainty*, Lowy Lecture Series, 17 August 2011, http://lowyinstitute.richmedia-server.com/sound/Uncharted_waters_US_alliance.mp3.
[96] McDougall, *The Heavens and the Earth*, 177.
[97] Trevor J Thomas, "Echo On The Line-ADF Joins WGS for NCW Forces," *Australian Defence Business Review*, October 2007.
[98] Peter B Selding, "Canada Officially Joins U.S. WGS Satellite Program," *Space News*, January 17, 2012, sec. Military.
[99] "Australian Defence Force Extends Hosted Payload Contract on Intelsat 22," April 28, 2010, http://www.intelsat.com/press/news-releases/2010/20100428-1.asp; "Australian Defence Force Extends Hosted Payload Contract on Intelsat 22"; Australia. Dept. of Defence., *Defending Australia in the Asia Pacific Century*, 82.

not a full description of Australian space capability acquisition (these are very platform centric after all), but merely demonstrate sophisticated approaches through cost sharing and shared payloads.[100]

Military

Since the launch of Sputnik, the military has been wholly grafted to space, and save undergoing traumatic surgery to remove its presence, spacepower will remain a fundamental enabler, and therefore also a potential vulnerability of military power, for the foreseeable future.

However, for Australia spacepower is not viewed in the same way as air, sea, or land power. That is to say, spacepower is not understood as an integral element of military power, in the same way that air power is seen as a vital component to dominating an air-sea gap (more on that later). This is attributable to a lack of working familiarity with spacepower, a lack of education as to what constitutes and sustains spacepower, and complacency because Australia benefits from the capabilities of other nations. It is also a historical legacy. As previously stated, Australia has fought in a full spectrum of war and conflict across the globe. Through this, the Australian military has become highly professional, well equipped, and trained to a high standard—but its frame of reference comes from the bloody experiences of conventional forces. From a Kuhnian systems perspective, the Australian military has become very good at operating within an existing paradigm, but the nature of spacepower demands a shift and reframing of the situation.

Geography

The expression most often used to describe Australia's defensive posture clearly reflects its geographical underpinnings, focused as it is on the "sea-air gap" to the north of Australia.[101] As an island continent

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[100] Biddington, Sach, and Kokoda Foundation., *Australia's Place in Space*, 58.
[101] Australia. Dept. of Defence., *Defending Australia in the Asia Pacific Century*, 51.

separated geographically from the many nations surrounding it (see Figure13), the sea-air gap provides depth for detection and response.[102] From this notion, the origins of Australia's particular defense capabilities become apparent: long-range air power to detect, identify and strike; coupled with early warning intelligence; and, as a final arbiter—sea power to protect Australia's maritime approaches. The latest Defence White Paper perpetuates the notion of geographic defense by specifying acquisition of significant submarine forces as a hedge against China's *potential* expansion in the Asia-Pacific region, while reinforcing a priority for highly capable air power.[103] While Australia's defensive strategy has remained consistent and clearly articulated, is the notion of spacepower forgotten, ignored, or adequately addressed?

Figure 13: Australia in the Asia-Pacific region

Source: CIA - The World Factbook

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[102] Australia. Dept. of Defence., *Defending Australia in the Asia Pacific Century*, 51.
[103] Australia. Dept. of Defence., *Defending Australia in the Asia Pacific Century*, 70,78.

Spacepower adds phenomenal depth to what is already a geographic strength. Unlike airpower that is constrained from overflight of sovereign borders, spacepower is continually moving overhead, crossing terrestrial borders, potentially a mere 200 km above the territory of any nation. This concept changes the way spacepower should be viewed. A theory of geopolitics says that national identities are still inherently derived from notions of territory, space, and place—in two dimensions.[104] International law dictates that seapower, and similarly airpower must maintain a distance of 12 nm from the territorial baseline of a nation state, and adjacent nations on land recognize a border as a geographical line—another two-dimensional construct.[105] For spacepower, it is as if another territory exists in parallel to the surface of the Earth, a shell of potential access stretching overhead that is difficult to fathom without an appreciation of orbitology (see Figure 14 for a representation). This overhead territory brings the geography of spacepower into sharp relief, increasing the two dimensional notion of depth we derive from a traditional map view.

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[104] David Newman, *Boundaries, Territory and Postmodernity*, cited in; School of Advanced Military Studies, *Art of Design*, 83.

[105] *United Nations Convention on the Law of the Sea*, n.d., http://www.un.org/depts/los/convention_agreements/texts/unclos/part2.htm; *Convention on International Civil Aviation Signed at Chicago on 7 December 1944*, 1944, http://www.icao.int/publications/Documents/chicago.pdf; the Chicago Convention precludes state aircraft (military, police, customs) from flying over the territory of another State.

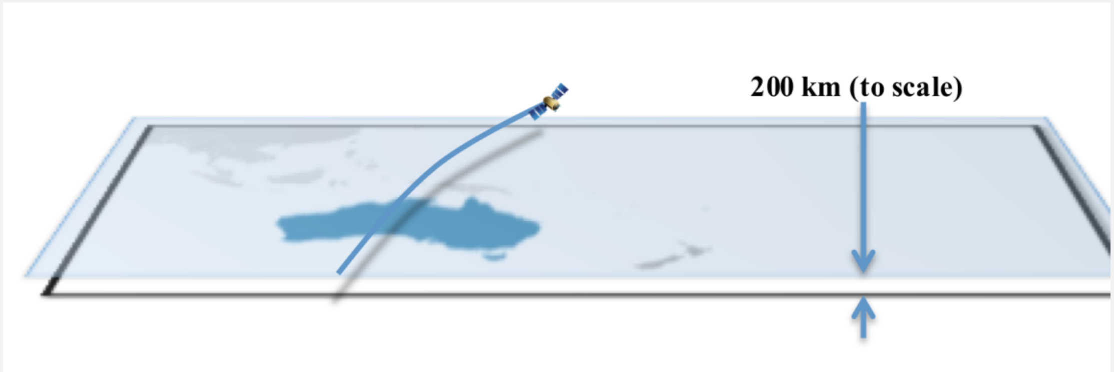

Figure 14: Spacepower Layer Overlay

Source: Authors original work modifying Figure 13

Space System Outputs

Having completed a framing of a spacepower situation for Australia in the preceding sections, the next step is to select *relevant* systems and describe what they are, not what needs to be done to improve or change them—something Checkland calls a "root definition."[106] The mind-map for the space system reveals what may be seen as something much simpler than the many specific roles that could be listed, in essence comprising only three elements: a sensing system, an information transfer system, and a spatial reference system. Each of these systems are then considered briefly for their influence on the larger system outside of space systems, thereby revealing the interconnections and couplings space has with factors of grand strategy—diplomatic, military, informational and economic.

Sensing System

The sensing system comprises all those capabilities (terrestrial included) and platforms that lead to useful outputs, such as weather (both terrestrial and in space), mapping, and military intelligence, among other things. As a demonstration of why a root definition has value, consider the simplified expression *sensing system* as compared to the

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[106] Checkland, *Systems Thinking, Systems Practice*, 166–168.

many means of energy reception partly demonstrated in Figure 15. In active sensing, energy is transmitted from space to Earth, reflected and then received for processing. Active energy forms include different Radar wavelengths and LIDAR (LIght Detection And Ranging)—the use of lasers. Passive energy is received by space sensors in the form of reflected visual energy (from the sun), emitted infra-red energy, ultra-violet, multi-spectral, communications frequencies, and so on.

Furthermore, within each output, there are numerous means to make use of the data in novel ways. One example is using highly precise height calculations based on synthetic aperture radar, coupling this with a calculation of coherence based on the phase change in received energy, and contrasting this with images from different times to derive where a change in surface has occurred, a technique called Coherent Change Detection, or CCD. Examples of where this might be used include: pre- and post-earthquake affected areas to determine where the ground has shifted, to accuracies within centimeters; or to see when farmland is being worked. The sub-groups continue in complexity and depth, and only briefly considered here to demonstrate the underlying complexity. The simpler, but descriptive, root definition of the sensing system encapsulates the sensing system as follows:

- Sensing conversion system - a standoff system in space to sense distinctive energy bands from the electromagnetic spectrum, convey the sensed information to earth, and turn it into intelligence.

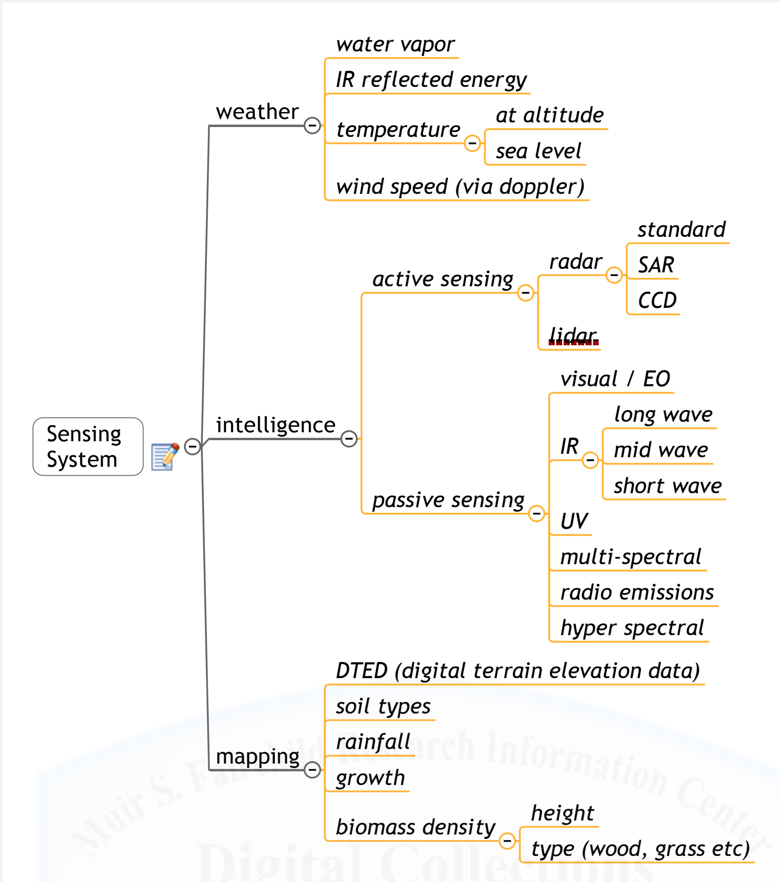

Figure 15: Sensing System Subgroups

Source: Authors original work.

For the sensing system, Australia is highly dependent upon the US for access to military information, and highly dependent upon international commercial providers for the remainder. *Access* to the information stands out as a critical vulnerability, as Australia does not have any national mitigation in terms of national capability. Agreements, regimes, and partnerships are the typical means to strengthen access to capability, and can improve deterrence potential through treaties. In a recent example, the US and Australian Governments agreed that a cyber-

attack on either one of them would trigger the ANZUS treaty.[107] The ANZUS alliance is at the heart of Australia's foreign and defense policy—demonstrated when Australia entered into the Global War On Terror under ANZUS in the days following the terrorist attacks on 9/11.[108] Improved resilience for Australia does not necessarily mean it should develop its own capabilities, but to what extent is Australia at risk? The likely significance of the loss or disruption of the sensing system warrants significant further consideration under a systems framework from a national security perspective.

Information Transfer System

The information transfer system is an answer to a terrestrial problem, how to transfer information using electromagnetic radiation over large distances? This derives from two other needs, to convey information without wires, as is the case for ship to shore transmissions, and secondly, for direct line of sight communications, to account for the curvature of the Earth. Certainly, radio waves can and have been used indirectly in the form of high frequency (HF) radio bounced off the ionosphere to bypass the limiting effect of the Earths curvature—but the bandwidth, or information able to be carried in HF is low, and subject to variations as the reflecting ionosphere moves throughout the day. For high bandwidth radio signals (such as: UHF, Ku, Ka) the path traced by the signal is a straight line, therefore the distance between them is practically limited by their height above the earth. For example, the line of sight distance between two towers of 30 m height is only 44 km.[109]

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[107] "Cooperation on Cyber – a New Dimension of the US Alliance, Media Release, Australian Minister for Foreign Affairs."

[108] Joseph Siracusa, "The ANZUS Treaty Revisited," *Security Challenges* 1, no. 1 (2005): 89, 103.

[109] A. G Bole, Alan Wall, and W. O Dineley, *Radar and ARPA Manual* (Oxford; Boston: Elsevier/Butterworth-Heinemann, 2005), 192; using equation radar range in nm = 1.2 square root of height in feet.

Space, though, effectively negates curvature and geometric restrictions. By cutting out a need for multiple terrestrial towers, this system builds on the extant advantages of wireless communications and has become a quintessential element of modern global communications. Accordingly, the root definition of the information transfer system is:

- A system that bypasses limitations due to the Earths curvature by capturing electromagnetic radiation and redirecting it from the vantage of space.

According to a senior USAF space commander, more satellite networks have been taken out by backhoes (a tractor used for digging trenches) than any other reason.[110] This demonstrates that system vulnerabilities do not always derive from the platform itself—a traditional focus area for risk assessments. Australia is an island continent; therefore, apart from its undersea communication cables, its only access to outside information is via space—a point not lost on the US embassy in Canberra. It identified the undersea connections as important to US/Australian connectivity, suggesting that they be classified as critical infrastructure on the *US* register.[111] The information transfer system via space is of enormous benefit to the isolated and geographically large continent of Australia—it may also be its Achilles Heel.

Spatial Reference System

The spatial reference system consists of a synchronized network of satellites with very accurate clocks transmitting coded information to receivers. Positional receivers, the most common being the US Global Positioning System (GPS), use the known location of networked satellites

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[110] Lt. Gen. Larry James, USAF, "JFCC Space Mission Brief" (presented at the Australian Defence Space Seminar 2010, Australian War Memorial, Canberra, March 24, 2010).

[111] Brendan Nicholson, "Undersea Cables Key to Security," *The Australian*, September 2, 2011, http://www.theaustralian.com.au/national-affairs/defence/undersea-cables-key-to-security/story-e6frg8yo-1226127658531.

and trilateration to calculate position. Trilateration is a method of determining position through the intersection of spheres, unlike intersecting lines as is used in normal positional calculations. Accordingly, the root definition of the spatial reference system is:

- A synchronized network of geo-referenced satellites using extremely accurate clocks for receivers to calculate position in space and time.

Key to the success of GPS and other reference systems is accurate timing, enabled by atomic clocks and a ground based timekeeper to synchronize the network.[112] Another defining feature of GPS is that the received signal is very weak, actually lower than the ambient noise level necessitating sophisticated technology to enable transmitted coded messages to be deciphered. The signal strength measured at the surface of the Earth ($1x10^{-16}$ Watts) is equivalent to viewing a 25-Watt light globe from a distance of 16,000 km.[113] It is now well known that a low power jammer of 1 watt (this can be made in a soda can sized device) is able to prevent tracking out to 10 km, even for a GPS receiver already locked into a solution.[114] And although military receivers are less sensitive to jamming than commercial products, both can be jammed with relatively small amounts of energy using simple coding that is readily available from knowledge of the nature of the GPS signal.

Barring widespread direct attack from anti-satellites, the GPS system is quite robust and well maintained by the US. The development of other space-based spatial reference systems such as China's *Beidou*

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[112] Roftiel Constantine, *GPS and Galileo: Friendly Foes?* (Maxwell Air Force Base, Ala.: Air University Press, 2008), 10.
[113] Jon S Warner and Roger Johnston, *GPS Spoofing Countermeasures* (Los Alamos National Laboratory, n.d.), 2, http://lewisperdue.com/DieByWire/GPS-Vulnerability-LosAlamos.pdf.
[114] John A Volpe, *Vulnerability Assessment of the Transportation Infrastructure Relying on the Global Positioning System.* (National Transportation Systems Center, August 29, 2001), 30.

(Compass), or the European Union's *Galileo* can be perceived as a threat through reducing the importance of the US GPS as a prime provider of service; but can also be seen as an opportunity to improve resilience of the system through redundant paths for information. For Australia, the loss of positional information *or* accurate timing would be devastating to many system outputs. Commercial shipping and aviation might halt for fear of accident, and a complex web of electronic transactions becomes untenable due to the loss of an accurate external time source.

Obviously, position and timing were sufficient for navigation before the advent of a spatial reference system in the form of GPS, so what has changed? As the utility of GPS has become apparent, its essentially free service (paid for by the US) and pervasive presence has almost guaranteed its entrenchment in a host of processes. As discussed in systems theory, providing the system that relies on its outputs is not stretched beyond capacity, then the system has an inherent resilience greater than its individual elements. However, catastrophic and cascading failure is more likely if the system limit is exceeded.

The integration of spatial reference services into societal sub-systems is truly staggering. In just one application, precise positioning in agriculture has led to the automation of crop harvesting—a quantum leap in technology that brings industrial age capabilities of mechanization into the knowledge age.[115] Other examples include electronic switches, cargo movement, traffic safety, logistics tracking, just in time logistics, precision agricultural harvesting, and remotely piloted vehicles.[116] Studies suggest modern societal systems would collapse as soon as three days after the spatial reference system was

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[115] Jeff Kueter in; Ed Morris et al., *A Day Without Space: Economic and National Security Ramifications* (The George C. Marshall Institute, October 16, 2008), 21.
[116] See Morris et al., *A Day Without Space: Economic and National Security Ramifications*.

degraded, or as far out as thirty days.[117] Whether the former or latter, the message is clear—space dependence underpins modern society. What is not clear is what to do about such dependence.

For Australia, and indeed the world, improved resilience (*sans* GPS) comes at a cost that is too great for any one individual user to bear. However, before that cost or options can be quantified, significant study of the system framework is required, and priority given for such work. It will require cross-disciplinary interaction, mapping of nebulous system architectures, and holistic thinking—all traits of complex system analysis. This can only come through strategic guidance at the highest levels of government—that is, through grand strategy.

How the intelligence derived from the space system is used is a subject of much discussion, but there appears to be little detailed analysis to support many of the statements. This does not suggest the experts are wrong, rather, the difficulty of determining how space outputs are critical enablers of other sub systems is indeterminate without a significant and larger systems analysis. For example, in the ground breaking forum *A Day Without Space: Economic and National Security Ramifications,* many scenarios were proffered for what might happen due to the loss of space system outputs, but very few real-life examples are available to support some of the more dire scenarios—a problem with any high consequence, low probability scenario.[118] Nonetheless, the systems approach reveals connections without necessarily categorizing and defining each and every node—dependence, criticality, failure potential, are all interesting from a deterministic perspective, but difficult to do and potentially short lived as an analysis

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[117] Ed Morris and John Sheldon in; Morris et al., *A Day Without Space: Economic and National Security Ramifications*, 5, 40.
[118] See Morris et al., *A Day Without Space: Economic and National Security Ramifications*.

CONCLUSION

The first decade of the twenty-first century has been marked with a plethora of new security concerns not tied to the conventional palette of issues one could expect to present itself to government in the century prior. Complexity, inter-connectedness, globalization, shifting power dynamics, dwindling resources, environmental concerns, and cyber security are just some of the new lexica that now accompany the issues of security and defense.[1] Despite the increased complexity of systems underwriting our societies, and hence a commensurate increase in the complexity of strategy, there is nonetheless a central unity that permeates all strategic experience.[2] Strategy is still strategy despite differences and changes in the historical, geographical or technological context; however, the way in which the problem is framed animates the way strategy is enacted. The desired ends of a nation change as understanding of the true nature of things becomes apparent.[3]

Carl Von Clausewitz was quoted in the opening chapter as saying, "Everything in strategy is very simple, but that does not mean that everything is very easy."[4] Then, somewhat disingenuously, he explained that once *what* is to be achieved has been determined (the simple part), it is easy to chart the course. I say disingenuously because Clausewitz also precedes his statement with, "it is only in the highest realms of strategy that intellectual complications and extreme diversity of factors and relationships occur."[5] The reality today is in these high realms of *grand strategy*; strategy, policy, and politics are blended to direct limited

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[1] Kevin Rudd, "First National Security Statement to the Australian Parliament, Address by the Prime Minister of Australia, The Hon. Kevin Rudd MP," December 2008, 4.
[2] Gray, *Modern Strategy*, 3, 354.
[3] Gray, *Modern Strategy*, 4.
[4] Clausewitz et al., *On War*, 178.
[5] Clausewitz et al., *On War*, 178.

resources towards the ends sought; and “intellectual complications” make strategy anything but easy.[6]

Grand strategy discounts a purely military view. As a process of weaving all the elements of national power towards a desired end, it raises the perennial strategist’s dilemma—between a realist and idealist paradigm. In the former, realism mitigates the risk of a loss in war, but potentially leads towards the development of excessive military force. In the latter, idealism distributes the wealth of the state broadly, but might fail in the critical duty of safeguarding state survival through insufficient preparation for the use of force. As a historical parallel, Walter McDougall, in his epic *…The Heavens And The Earth,* emphasized the dilemma of the space race; between a race to dominate militarily and economically, and the dangers of a growing technocracy to enable such dominance that might erode the “very values that make one’s society worth defending in the first place.”[7]

This highlights the complexity of modern strategy, and emphasizes the need for a grand strategy to reconcile a multitude of national requirements by widening the lens of observation to encompass a greater field of view. What is needed is a dispassionate perspective that addresses the concerns of war (particularly a loss in war), while weighing the investment costs against other choices. Unfortunately, a common view of the world, linear, mechanistic, and reductionist; is unable to address the complexity inherent in modern systems. A systems lens is needed.

An understanding of the broader space system and the interaction of elements is more useful to grand strategy than a narrow understanding of its individual elements. Yet, such understanding is influenced by factors such as exponential growth and difficulty in

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[6] Clausewitz et al., *On War*, 178.
[7] McDougall, *The Heavens and the Earth*, 13.

understanding the many interdependent parts within the system. Risk assessment and management is one standard approach to deal with such problems, and this approach as used by government and industry was investigated for its usefulness in efficiently mitigating risk in complex systems. For highly improbable yet highly consequential events, risk analysis was found to be seriously inadequate, necessitating a rethink on how we manage the most important capabilities underpinning society. Furthermore, the application of risk mitigation can only address perceived events (excluding that which is not foretold), and therefore fails to address highly improbable unforeseen events.

As an alternative to risk analysis for highly improbable events, alternate theories that also account for our poor human understanding of the highly improbable were evaluated to form a basis for a *strategy for complex systems*. Instead of a drive to negate risk, and forego pain, we should expect the unexpected, and instead design our systems for resilience. Although risk analysis remains a valid tool for many problems, a resilience focus became the subject of a space systems analysis to view dependency and mitigation in a different light. However, before such analysis, a theory of spacepower was needed to support the final systems analysis, thereby ensuring the meaningful elements were considered from a systems perspective.

In contrast to the mass of discussion and scholarly debate over terrestrial forms of power, relatively few active professionals and scholars have laid an enduring path for spacepower. This is partly due to humankind's relatively benign fifty years in space, exacerbated by a lethargic response of the main players, great powers who have benefited from the *status quo*. Consequently, spacepower theory suffers from a lack of intellectual investment, and we can infer from Clausewitz's dictum

that an absence of “intellectual complications”, though simpler to respond to, is less likely to foster grand strategy.[8]

Space; however, is no longer the exclusive domain of major powers, and its accessibility to a wider range of nations makes it subject to emerging issues that are also characteristic of complex systems. Though it is a domain that has been spared, to date, the devastation of direct conflict, it is an integral component of the conflict that has occurred terrestrially. Principles on which to base a theory have therefore not been drawn from a crucible of conflict as they have with the other domains. Consequently, each of the other domains: land, sea, air and cyber were evaluated for applicability and worth in developing a spacepower theory. Many analogies were transferable, but space is nonetheless distinct from the other domains—more complex and intertwined as a system, yet simpler in understanding when viewed as discrete orbiting satellites. This led to the definition of spacepower as: a measure of a nation’s ability to influence all operational environments and all instruments of power using the space system.

Having established spacepower as unique from other forms of power, a spacepower strategy for Australia might have been concocted using conventional notions of space as being nothing more than the domain surrounding satellites. However, the main purpose of a theory of strategy is to highlight what needs thinking about—to provide insight, not answers.[9] The most important aspect of good systems thinking is the ability to consider a wide range of possible relevant systems, model and discuss them, and be able to discard and reframe them as the debate initiated by the model/real world comparison unfolds.[10] The practical implementation of this for space as a system generated a systems view of spacepower, viewed in an Australian context. The investigation, though,

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[8] Clausewitz et al., *On War*, 178.
[9] Gray, *Modern Strategy*, 12.
[10] Checkland, *Systems Thinking, Systems Practice*, 223.

highlighted a critical need for more detailed modeling beyond this thesis to improve the fidelity and accuracy of the systems analysis. Such ongoing work is at the heart of systems theory, as an understanding of the system builds during the investigation, not through a focus on the destination.

A *dimensions of strategy* framework was used as a model for considering Australian strategy for the twenty-first century and the impact that spacepower (or lack thereof), might have. Coupled with a conceptual understanding of the *terroir* of space, and three main outputs derived from the space system, implications for an Australian spacepower were derived as follows:

- For spacepower to gain traction as an essential element of national security strategy, it needs to be addressed both politically and militarily, from a whole of government and joint military perspective.
- Spacepower is a high-payoff technology that requires lower human capital than other forms of military power (excepting cyberpower), making it appropriate for Australia's relatively small population.
- The traditional and familiar cultural response to Australian national security needs updating to account for complexity, and for spacepower.
- An Australian contribution to SSA has three benefits: it supports Australian niche technologies that are world class, it meaningfully contributes to Australia's strongest ally, and it contributes to improved space security for the benefit of all users.
- Discussions with Australia's principal ally, the US, should frame the space system as a larger, complex problem to be shared, or rather, contributed to by a larger pool of actors.

What might then result are collaborative and joint ventures where the whole is greater than the sum of the parts.

- Within the Australian Defence Organisation (ADO), strong support for spacepower and a supportive structure is ensuring the appropriate level of attention is being focused. Australia now sits on the cusp of making a meaningful and unique contribution to space security through SSA.
- Australia, as a relatively wealthy country might do more to develop relationships with regional space agencies, with the goal of developing greater resilience.
- Sophisticated approaches to acquire space system capabilities through cost sharing and shared payloads should continue.
- The Australian military has become very good at operating within an existing conventional warfare paradigm, but the nature of spacepower demands a shift and reframing of the situation.
- Spacepower adds phenomenal depth to what is already a geographic strength of Australia.

Having completed the framing of a spacepower situation for Australia, the space system may be seen as something much simpler than the many specific roles that could be listed, in essence comprising only three elements: a sensing system, an information transfer system, and a spatial reference system.

- For the sensing system, *access* to the information stands out as a critical vulnerability, as Australia does not have any national mitigation in terms of national capability.
- The information transfer system via space is of enormous importance to Australia—it may also be its Achilles Heel.
- The integration of spatial reference services into societies sub systems is truly staggering. Significant study of the system

> framework is required, and priority given for such work. It will require cross-disciplinary interaction, mapping of nebulous system architectures, and holistic thinking—all traits of complex system analysis. This can only come through strategic guidance at the highest levels of government—that is, through grand strategy.

Historically, a nation could separate domestic and international concerns, with different strategies applied to each—but they were different times. As the systems that enable a functioning, modern society increase in complexity, we know less about the effects of highly improbable yet highly consequential disruptions to the system. Space systems are a case in point. They permeate the fabric of modern society to such an extent that they have become an essential element of national security.[11] Nonetheless, we know little about such dependence because the system itself is too complex for conventional analysis.

By observing spacepower through a systems lens, it is apparent that it needs to be incorporated in to a national grand strategy—anything less fails to recognize its underlying importance and exposes the nation to catastrophe. Spacepower for Australia's security is not a strategy of grandeur; it is simply one essential element of an enduring grand strategy.

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[11] Sheehan, *The International Politics of Space*, 117.

ACRONYMS

ADF – Australian Defence Force

ADO – Australian Defence Organisation

CCD- Coherent Change Detection

CSpOC - Coalition Space Operations Center

DIME – Diplomatic, Information, Military, and Economic Power

DOD – Department of Defense

DSCO - Defence Space Coordinating Office

GDP – Gross Domestic Product

GEO – Geostationary Orbit

HEO – Highly Elliptical Orbit

LEO – Low Earth Orbit

LIDAR – Light Detection And Ranging

MEO – Medium Earth Orbit

PMESII – Political, Military, Economic, Social, Infrastructure, and Information systems

RAAF – Royal Australian Air Force

SPU - Space Policy Unit

SSA – Space Situational Awareness

SW – Schriever Wargame

USAF – United States Air Force

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